台灣農業研究

JOURNAL OF TAIWAN AGRICULTURAL RESEARCH

Vol.67 No.2 2018

Research Articles

107 Redescription of *Leptispa abdominalis* Baly, 1858 (Insecta: Coleoptera: Chrysomelidae: Cassidinae: Leptispini), Newly Recorded from Kinmen Island, with Notes on Its Biology
Chi-Feng Lee and Lukáš Sekerka

113 An Annotated Checklist of Mymaridae (Hymenoptera: Chalcidoidea) in Taiwan, with Descriptions of Five New Species
Serguei V. Triapitsyn

166 Population Dynamic and Spatial Distribution of the Citrus Rust Mite, *Phyllocoptruta oleivora* (Ashmead), on Three Varieties of Citrus in Taiwan
Po-Hung Chen, Tai-Chuan Wang, Chi-Nan Chen, Chiung-Hui Huang, and Shou-Horng Huang

181 Temperature-dependent Development and Life Table of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) on Mango
Hsin-Shun Lai, Yi-Ju Chen, Yi-Chung Chiu, and Feng-Chyi Lin

191 Phylogenetic Analysis and Occurrence of *Maize chlorotic mottle virus* Infecting Maize in Taiwan
Chien-Ming Chou, Chun-Tao Chen, Yi-Hsuan Chien, Chin-Hui Tsai, Chin-Chih Chen, Feng-Chyi Lin, Yi-Ju Chen, and Ting-Ching Deng

209 Improving Resistance to *Fusarium* Wilt Disease in PFLP Transgenic Bananas
Cheng-Ping Kuan, Po-Heng Chen, Han-Wei Chen, Teng-Yung Feng, and Tso-Chi Yang

Short Communications

218 *Panonychus elongatus* (Trombidiformes: Tetranychidae), a New Prosperous Crop Pest in Taiwan
Chyi-Chen Ho, Shun-Cheng Wang, Shih-Hsiang Liang, and Shu-Chen Chang

224 Hexanoic Acid Alleviated Cotton Aphid (*Aphis gossypii* Glover) Infestations in Cucumber
Yaw-Jen Dong and Bei-Chen Hsiu

ISSN 0022-4847
9 770022 484003

Published by Taiwan Agricultural Research Institute, Council of Agriculture

台灣農業研究 JOURNAL OF TAIWAN AGRICULTURAL RESEARCH Vol.67 No.2 2018

ISSN 0022-4847
DOI:10.6156/JTAR

台灣農業研究

JOURNAL OF TAIWAN AGRICULTURAL RESEARCH

Vol.67 No.2 2018

研究報告

107 金門產新記錄金花蟲：黃腹小扁鐵甲蟲的重新描述 (鞘翅目：金花蟲科：龜金花蟲亞科：小扁鐵甲蟲族)
李奇峯、Lukáš Sekerka

113 台灣纓小蜂科 (膜翅目：小蜂總科) 名錄記述暨五新種描述
Serguei V. Triapitsyn

166 柑橘銹蟎 [*Phyllocoptruta oleivora* (Ashmead)] 在三種柑橘上之族群動態與空間分布
陳柏宏、王泰權、陳祈男、黃瓊慧、黃守宏

181 溫度依變下小黃薊馬 (*Scirtothrips dorsalis* Hood) 在檬果上之發育及生命表
賴信順、陳怡如、邱一中、林鳳琪

191 玉米褪綠斑駁病毒 (*Maize chlorotic mottle virus*) 之親緣分析與台灣之發生調查
周建銘、陳君弢、簡伊萱、蔡錦慧、陳金枝、林鳳琪、陳怡如、鄧汀欽

209 基因轉殖PFLP香蕉於促進抗香蕉黃葉病之研究
關政平、陳柏亨、陳涵葳、馮騰永、楊佐琦

研究簡報

218 長莖全爪蟎 (*Panonychus elongatus* Manson) (絨蟎目：葉蟎科) ──一種新興的害蟎
何琦琛、王順成、梁世祥、張淑貞

224 己酸緩和棉蚜 (*Aphis gossypii* Glover) 對小黃瓜侵襲
董耀仁、許北辰

行政院農業委員會農業試驗所出版

《台灣農業研究》編審會

總編輯

楊純明／農業試驗所作物組

領域主編（按筆劃序）

王強生／國立中興大學農藝學系
王淑珍／國立台灣大學農藝學系
古新梅／國立中興大學農藝學系
安寶貞／農業試驗所植物病理組
吳文哲／國立台灣大學昆蟲學系
呂秀英／苗栗區農業改良場
杜宜殷／國立台灣大學園藝暨景觀學系
沈偉強／國立台灣大學植物病理與微生物學系
林彥蓉／國立台灣大學農藝學系
林慧玲／國立中興大學園藝學系
侯豐男／國立中興大學昆蟲學系
柯俊成／國立台灣大學昆蟲學系
高景輝／國立台灣大學農藝學系
張永和／靜宜大學食品營養系
張瑞璋／農業試驗所植物病理組
莊愷瑋／國立嘉義大學農藝學系
郭寶錚／國立中興大學農藝學系
陳世銘／國立台灣大學生物產業機電工程學系
陳右人／國立台灣大學園藝暨景觀學系
陳宗禮／國立中興大學農藝學系
陳郁蕙／國立台灣大學農業經濟學系
陳健忠／農業試驗所應用動物組
陳琦玲／農業試驗所農業化學組
曾夢蛟／國立中興大學園藝學系
黃振文／國立中興大學植物病理學系
黃裕銘／國立中興大學土壤環境科學系
黃肇家／農業試驗所作物組
黃鵬林／國立台灣大學園藝暨景觀學系
楊正澤／國立中興大學昆蟲學系
路光暉／國立中興大學昆蟲學系
鄒裕民／國立中興大學土壤環境科學系
劉力瑜／國立台灣大學農藝學系
蔡致榮／農業試驗所
鍾文鑫／國立中興大學植物病理學系
簡立賢／國立中興大學應用經濟學系
顏國欽／國立中興大學食品暨應用生物科技學系

編輯助理

吳惠卿／農業試驗所技術服務組
王紫瑜／農業試驗所《台灣農業研究》期刊編輯室
王立蓉／農業試驗所《台灣農業研究》期刊編輯室

編輯助理顧問

吳宜晏／農業試驗所技術服務組

台灣農業研究

第六十七卷　第二期　　中華民國一〇七年六月三十日

出版者　行政院農業委員會農業試驗所
發行人　陳駿季
總編輯　楊純明
地址　41362 台中市霧峰區萬豐里中正路 189 號
網址　http://www.tari.gov.tw
電話　(04)2331-7236
E-mail　jtar@tari.gov.tw
線上投審稿系統　http://aspers.airiti.com/JTAR

編印　Airiti Press
地址　23452 新北市永和區成功路一段 80 號 18 樓
電話　(02)2926-6006
E-mail　press@airiti.com

定價　新台幣一七五元
展售門市　1. 國家書店／ 10485 台北市松江路 209 號 1 樓 / 電話 : (02) 2518-0207
國家網路書店 http://www.govbooks.com.tw
2. 五南文化廣場／ 40042 台中市中山路 6 號 / 電話 : (04) 2226-0330

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):107–112 (2018)
DOI: 10.6156/JTAR.201806_67(2).0001

Research Article

Redescription of *Leptispa abdominalis* Baly, 1858 (Insecta: Coleoptera: Chrysomelidae: Cassidinae: Leptispini), Newly Recorded from Kinmen Island, with Notes on Its Biology

Chi-Feng Lee[1,*] and Lukáš Sekerka[2]

Abstract

Lee, C. F. and L. Sekerka. 2018. Redescription of *Leptispa abdominalis* Baly, 1858 (Insecta: Coleoptera: Chrysomelidae: Cassidinae: Leptispini), newly recorded from Kinmen Island, with notes on its biology. J. Taiwan Agric. Res. 67(2):107–112.

Leptispa abdominalis Baly, 1858, formerly known from China and Vietnam, is recorded from Kinmen Island. The species is redescribed, and illustrations of diagnostic characters are provided, including pronotum, aedeagus, gonocoxae, and spermatheca. Adults and larvae of this species construct leaf-rolls on *Bambusa* similar to those of *L. pygmaea* Baly.

Key words: Leaf beetle, Taxonomy, Host plant, Poaceae, Leaf-roll.

INTRODUCTION

Two species of the genus *Leptispa* were described from Taiwan by Chûjô (1933). Only one species actually occurs in Taiwan because the other species is a junior synonyms of it based on a recent study by the Taiwan Chrysomelid Research Team (Lee & Staines 2010). A series of specimens of *Leptispa* collected from Kinmen Island, near the southeastern coast of mainland China, were determined to represent a species not previously known from Taiwan and its island territories. They were identified as *L. abdominalis* Baly, 1858, originally described from Mainland China. We took the opportunity to redescribe this species and describe diagnostic characters that allow it to be distinguished from the Taiwanese species (*L. miwai* Chûjô, 1933).

MATERIALS AND METHODS

To prepare drawings of the adult reproductive systems, abdomens were separated and boiled in 10% KOH solution, cleared in distilled water, and mounted in glycerin on microscope slides for observation. Specimens were examined and drawings were made using a Leica M165 stereomicroscope. Morphological details were illustrated using a Nikon ECLIPSE 50i microscope. Body parts were then stored in glycerin tubes with the dry mounted specimens.

Specimens examined during this study are deposited in the following collections: BMNH: Natural History Museum, London, UK; MNHN: Museum national d'Histoire naturelle, Paris, France; NMPC: National Museum, Praha, Czech Republic; TARI: Taiwan Agricultur-

---

Received: August 25, 2017; Accepted: October 24, 2017.

[*] Corresponding author, e-mail: chifeng@tari.gov.tw
[1] Associate Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.
[2] Researcher, Department of Entomology, Natural History Museum, National Museum, Prague, Czech Republic.

al Research Institute, Taichung, Taiwan.

Exact label data are cited for all type specimens; a double slash (//) divides the data on different labels and a single slash (/) divides the data in different rows. Other comments and remarks are indicated as follow: (p) preceding printed data, (h) preceding handwritten data, (w) white labels, (b) blue labels and (r) red labels.

RESULTS AND DISCUSSION

Leptispa abdominalis Baly

Leptispa abdominalis Baly, 1858: 3; Gressitt, 1939a: 164 (redescription); Gressitt, 1939b: 199 (China: Guangdong); Gressitt, 1950: 74 (redescription); Gressitt & Kimoto, 1963: 903 (China: Guangdong); Chen *et al*., 1986: 405.

Leptispa atripes Pic, 1925: 16 (Vietnam); Medvedev, 1992: 151 (as synonym of *L. abdominalis*).

Leptispa conicicollis Voronova & Zaitzev, 1982: 121 (Vietnam); Medvedev, 1992: 151 (as synonym of *L. abdominalis*).

Type specimen examined. *Leptispa abdominalis*: Holotype (BMNH), sex undetermined, by monotypy, labeled: "Type/H.T. [p, w, circle label with red border] //N. China [p, w] //Baly Coll. [p, w] //Leptispa/abdominalis/Baly/N. China [w, b]."

Leptispa atripes: Holotype (MNHN), sex undetermined, by monotypy, labeled: "Dap Yam/Sau 24.2.06 [h, w] //Leptispa/n. sp. [h, w] //TYPE [p, r] //Type [h, w] //Museum Paris/ Coll. M. Pic [p, w] //atripes/n. sp. [h, w]."

Leptispa conicicollis: in Medvedev's collection, not studied.

Redescription. Length 5.9–6.8 mm, width 1.8–2.0 mm. Overall color black, but legs dark brown and abdomen yellow (Figs. 1A–1C). Anterior margin of head rounded and emarginate, disk with dense puncture and reticulate microsculpture. Pronotum (Fig. 2A) square, disk with reticulate microsculpture only apically, with random coarse punctures interspersed with numerous minute punctures. Elytra elongate, about 2.6–2.7 times longer than wide, parallel-sided, disk with one longitudinal ridge between striae VIII and IX. Penis (Figs. 2D–2E) strongly curved near base; strongly and apically narrowed, apex truncate; internal sac with one elongate sclerite, basally bifurcate, straight in lateral view. Gonocoxae (Fig. 2G) separated, small, triangular. Spermathecal receptacle (Fig. 2C) strongly swollen, pump much narrow and strongly curved.

Diagnosis. *Leptispa abdominalis* differs from *L. miwai* in the following combination of characters: pronotum with punctures of the same size (Fig. 2A) [coarser punctures at sides of the pronotum in *L. miwai* (Fig. 2B)], yellow abdomen and dark brown legs (Figs. 1A–1C) [black abdomen and legs in *L. miwai* (Fig. 1D)], narrower elytra (Fig. 1A) [broader elytra in *L. miwai*, 2.2–2.4 times longer than wide (Fig. 1D)], presence of longitudinal elytral ridge between striae VIII and IX [reduced in *L. miwai*], strongly narrowed apex of penis (Fig. 2D) [slightly narrowed apex in *L. miwai*], straight endophallic sclerite (Fig. 2E) [strongly curved sclerite in *L. miwai*], reduced and triangular gonocoxae lacking dense setae (Fig. 2G) [well developed gonocoxae with dense setae in *L. miwai* (Fig. 2F)].

Other material examined. CHINA: Guangdong: 2 exs. (BMNH), Honam Island [湖南島], 2.VII.1926, leg. W. E. Hoffman; Hong Kong: 1 ex. (BMNH), 1911-359, leg. F. W. Terry; **TAIWAN:** Kinmen: 6 exs. (TARI, NMPC), Botanic Park [植物園], 13.VI.2015, leg. Y.-J. Chang; 9 exs. (TARI, BMNH), Shuitou Village [水頭聚落], 21.XI.2016, leg. S.-F. Yu, hand collecting.

Biology. Gressitt (1950) reported bamboo as the host plant for *Leptispa abdominalis* without further information. In this study, we found specimens feeding on leaves of *Bambusa pachinensis* var. *pachinensis* Hayata, 1916 [八芝蘭竹] (Fig. 3A). Larvae (Figs. 3C–3D), pupae (Fig. 3E), and adults (Fig. 3F) were found in different longitudinally oriented leaf-rolls (Fig. 3B). Construction of such leaf-rolls was previously reported only for *Leptispa pygmaea* Baly (Prathapan *et al*. 2009). Thus, this is the

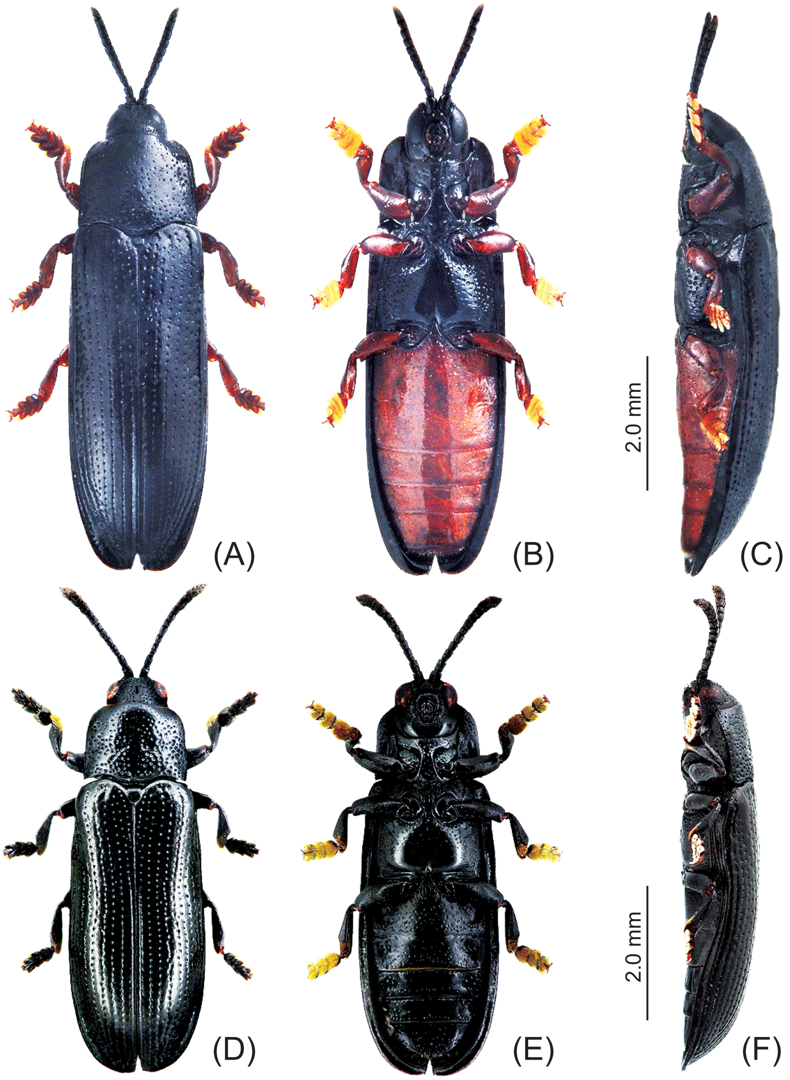


Fig. 1. Color habitus of *Leptispa abdominalis* and *L. miwai*. (A) *L. abdominalis*, collected from Shuitou Village [水頭聚落], Taiwan, dorsal view; (B) Ditto, ventral view; (C) Ditto, lateral view; (D) *L. miwai*, from Yingtzuling [鶯子嶺], Taiwan, dorsal view; (E) Ditto, ventral view; and (F) Ditto, lateral view.

second species documented with such behavior.

Distribution. China, Taiwan (only Kinmen Island, new record), Vietnam.

ACKNOWLDGMENTS

We thank firstly Yung-Jen Chang for discovering this species in Kinmen Island. We thank the Taiwan Chrysomelid Research Team for assisting in various ways, including Su-Fang Yu and Mei-Hua Tsou for taking field photographs and collecting specimens; Ta-Hsiang Lee and Kai-Siang Jhan for photographs of specimens; and Chih-Kai Yang for identification of the host plant. We thank Chris Carlton for reading the draft and editing for American English style. This study was supported by the Ministry of Science and Technology (MOST 105-2313-B-055-001-MY2).

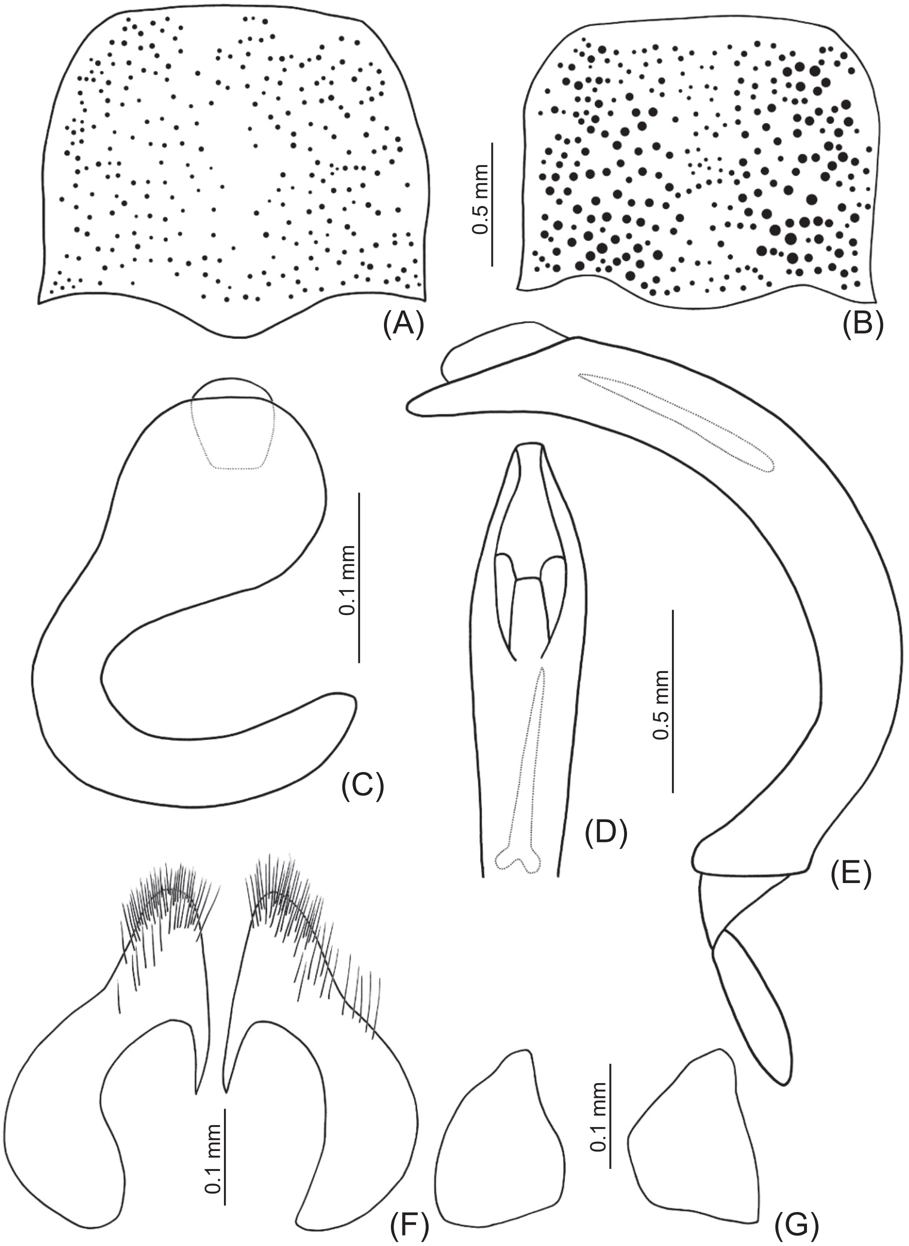


Fig. 2. Diagnostic characters of *Leptispa abdominalis* and *L. miwai*. (A) *L. abdominalis*, pronotum; (B) *L. miwai*, pronotum; (C) *L. abdominalis*, spermatheca; (D) *L. abdominalis*, apex of penis, dorsal view; (E) *L. abdominalis*, penis, lateral view; (F) *L. miwai*, gonocoxae; and (G) *L. abdominalis*, gonocoxae.

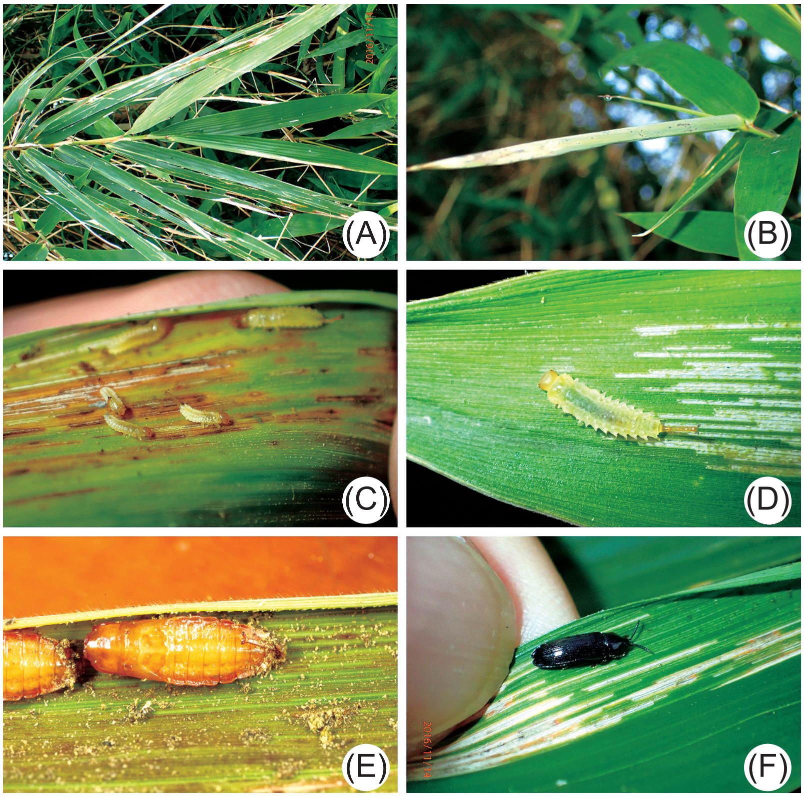


Fig. 3. Field photographs for *Leptispa abdominalis*. (A) Host plant, *Bambusa pachinensis* var. *pachinensis*; (B) leaf-roll constructed by larvae; (C) young larvae; (D) older larva; (E) pupae; and (F) adult.

REFERENCES

Baly, J. S. 1858. Catalogue of Hispidae in the Collection of the British Museum. British Museum. London, UK. 172 pp.

Chen, S., P. Yu, C. Sun, and Y. Zia. 1986. Fauna Sinica Insecta. Vol.2. Coleoptera: Hispidae. Science Press. Beijing, China. 653 pp. (in Chinese)

Chûjô, M. 1933. Studies on the Chrysomelidae in the Japanese Empire (IV). Trans. Nat. Hist. Soc. Formosa 23:304–334.

Gressitt, J. L. 1939a. Hispine beetles in the collection of the Lingnan Natural History Survey and Museum (Coleoptera: Chrysomelidae: Hispinae). Lingnan Sci. J. 18:161–186.

Gressitt, J. L. 1939b. Some hispine beetles from southeastern China (Coleoptera: Chrysomelidae: Hispinae). Lingnan Sci. J. 18:197–208.

Gressitt, J. L. 1950. The hispine beetles of China (Coleoptera: Chrysomelidae). Lingnan Sci. J. 23:53–142.

Gressitt, J. L. and S. Kimoto. 1963. The Chrysomelidae (Coleopt.) of China and Korea. Pac. Insects Monogr. 1B:301–1026.

Lee, C. F. and C. L. Staines. 2010. The genus *Leptispa* in Taiwan (Coleoptera: Chrysomelidae: Cassidinae: Letispini). Genus 21:265–269.

Medvedev, L. N. 1992. Revision of the subfamily Hispinae (Coleoptera, Chrysomelidae) in the fauna of Vietnam. Part 1. p.127–156. *in*: Systematization and Ecology of Insects of Vietnam. (Medvedev, L. N., ed.) Nauka Press. Moscow, Russia. 264 pp. (in Russian)

Pic, M. 1925. Nouveautés diverses. Mélanges Exotico-Entomologiques 43:1–32.

Prathapan, K. D., C. S. Chaboo, and K. Karthikeyan. 2009. Natural history and leaf shelter construction of the Asian rice Leptispa beetle *Leptispa pygmaea* Baly (Coleoptera: Chrysomelidae: Cassidinae: Leptispini). Zool. Stud. 48:625–631.

Voronova, H. B. and Y. M. Zaitsev. 1982. The genus *Leptispa*-pests of bamboo in Vietnam. p.115–124. *in*: Animal World of Vietnam (Medvedev, L. N., ed.) Nauka Press. Moscow, Russia. 167 pp. (in Russian)

金門產新記錄金花蟲：黃腹小扁鐵甲蟲的重新描述 (鞘翅目：金花蟲科：龜金花蟲亞科：小扁鐵甲蟲族)

李奇峯[1,*] Lukáš Sekerka[2]

摘要

李奇峰、Lukáš Sekerka。2018。金門產新記錄金花蟲：黃腹小扁鐵甲蟲的重新描述 (鞘翅目：金花蟲科：龜金花蟲亞科：小扁鐵甲蟲族)。台灣農業研究 67(2):107–112。

黃腹小扁鐵甲蟲 (*Leptispa abdominalis* Baly, 1858) 原本只分布在中國及越南，目前已在金門發現並作重新描述。針對診斷特徵以線圖描繪，包括前胸背板、雄性生殖器、雌蟲生殖突基節及雌蟲受精囊，並對其食草及捲葉行為做進一步的探討。

關鍵詞：金花蟲、分類學、寄主植物、禾本科、捲葉。

投稿日期：2017 年 8 月 25 日；接受日期：2017 年 10 月 24 日。

[*] 通訊作者：chifeng@tari.gov.tw
[1] 農委會農業試驗所應用動物組聘用副研究員。台灣 台中市。
[2] 國立自然史博物館昆蟲組研究員。捷克 布拉格。

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):113–165 (2018)
DOI: 10.6156/JTAR.201806_67(2).0002

Research Article

An Annotated Checklist of Mymaridae (Hymenoptera: Chalcidoidea) in Taiwan, with Descriptions of Five New Species

Serguei V. Triapitsyn[1,*]

Abstract

Triapitsyn, S. V. 2018. An annotated checklist of Mymaridae (Hymenoptera: Chalcidoidea) in Taiwan, with descriptions of five new species. J. Taiwan Agric. Res. 67(2):113–165.

A checklist of the fairyflies (Hymenoptera: Mymaridae) known from Taiwan is presented, annotated with information on their distribution and host associations. There are 28 genera and 60 named species, among them 13 genera and 33 species are new records for Taiwan. The five new species described here are *Acmopolynema berezovskiyi* sp. nov., *Anagroidea montana* sp. nov., *Camptoptera jthuberi* sp. nov., *Mymar alishan* sp. nov., and *Ooctonus kokozai* sp. nov. The male of *Eubroncus orientalis* Yoshimoto, Kozlov and Trjapitzin, 1972 (the type species of the genus *Eubroncus* Yoshimoto, Kozlov and Trjapitzin, 1972) is redescribed, and its previously unknown female is described based on specimens from Sulawesi Island, Indonesia; an updated world key to the species of *Eubroncus* is provided. *Eubroncus hani* Jin and Li, 2014 syn. nov. is synonymized under *Eubroncus indicus* Hayat and Khan, 2009, whose male is described here based on specimens from Nepal; the previously-unknown males of *Cosmocomoidea tenuis* Xu, Lin and Hu, 2016 and *Eubroncus tibetanus* Jin and Li, 2014 are also described based on specimens from Taiwan and Japan, respectively. As egg parasitoids, some members of the family are important as natural enemies of agricultural pests, such as rice planthoppers and leafhoppers (Hemiptera: Delphacidae and Cicadellidae, respectively); previous records of these in Taiwan are critically analyzed.

Key words: Mymaridae, List, New species, Taiwan, Egg parasitoid.

INTRODUCTION

Mymaridae, or fairyflies (Hymenoptera: Chalcidoidea) are a rather large, speciose family whose members are, with very few exceptions, egg parasitoids of various insects. As such, some species are important as natural enemies of agricultural pests, such as rice planthoppers and leafhoppers (Hemiptera: Delphacidae and Cicadellidae) (Triapitsyn 2002, 2013a, 2013c). Taguchi (1974, 1975, 1977a, 1977b, 1978) published on taxonomy of the genera *Camptoptera* Foerster, 1856, *Himopolynema* Taguchi, 1977, *Mymar* Curtis, 1829, *Palaeoneura* Waterhouse, 1915, and *Stephanodes* Enock, 1909, which contain descriptions of several new species from Taiwan. Unfortunately, the entire Dr. Hidenari Taguchi collection of Mymaridae, which was supposed to be deposited in the Entomological Laboratory, College of Agriculture, Ehime University, Matsuyama, Japan (EUMJ), has never made it there, being lost from his home, including the types (Huber 2003; Triapitsyn 2014b, 2015a). More recently, Triapitsyn (2015a) and Triapitsyn *et al*. (2017) added several new species to

Received: June 1, 2017; Accepted: October 27, 2017.
* Corresponding author, e-mail: serguei.triapitsyn@ucr.edu
1 Principal Museum Scientist, Department of Entomology, University of California, Riverside, CA, USA.

the knowledge of the mymarid fauna of Taiwan and designated neotypes for the species of *Himopolynema* described in Taguchi (1977a). The same remains to be done for his species of *Camptoptera* and *Palaeoneura*, but freshly collected, matching specimens of these genera from or near their type localities in Taiwan are unfortunately lacking.

Tian *et al*. (2006) reported a surprisingly low generic diversity index for the Mymaridae of Taiwan which they suggested, along with Tibet's, to be significantly lower than that for Fujian, China; however, that is certainly a misleading conclusion because the mymarid fauna of Taiwan was, at that time (and still is, despite some recent progress), poorly known and is, like that of Fujian, mostly Oriental, with some Palaearctic and other elements. One would expect, due to the large size of the island, the diversity of its habitats, and relative proximity to mainland China, greater diversity than reported, and some endemism (particularly in the mountains). The ability of fairyflies to be dispersed by wind would also mitigate that, so more likely, the mymarid fauna of Taiwan could be almost as diverse as that of nearby Fujian (as listed by Lin & Xu 2003), at least at the generic level. However, thorough collecting efforts of the family in Taiwan have been lacking recently, so few fresh specimens of good quality are currently available to properly assess the true diversity. For that reason, and also because one could expect at least five more genera to occur in Taiwan besides the 28 genera listed here (13 newly recorded), providing a key to the mymarid genera of Taiwan would be pointless at this time; for the time being, these can be mostly identified using the available generic keys for the Oriental region (Subba Rao & Hayat 1983) and China (Lin & Xu 2000), as well as for the Palaearctic region (Triapitsyn & Huber 2000) for specimens collected at high altitudes.

During the 1950s–1970s, Kwei-Shui Lin (1921–2002), a taxonomist and prolific collector of parasitic Hymenoptera, who worked at the Taiwan Agricultural Research Institute (TARI) in Taipei City before moving to Taichung, captured almost 3,000 mymarids throughout Taiwan (the bulk are from Taipei City and its environs). Unfortunately, these represent just a few genera (most specimens belong to those in the tribe Gonatocerini, some of which I sorted to genus and species) and were almost all rather poorly mounted, without proper clearing and positioning, on individual slides. These are all labeled in English and kept in about 30 slide boxes in the insect collection of the TARI, Wufeng, Taichung, Taiwan, Republic of China, besides just a few air-dried, dry-mounted specimens on points. His collection has proven to be an invaluable resource for this study, and also for my previous publication on *Himopolynema* of Taiwan (Triapitsyn 2015a).

Lin (1974), Miura *et al*. (1981), and Chen (1993) reported on egg parasitoids of the rice leafhoppers and planthoppers in Taiwan; Chen & Yu (1989) studied *Anagrus* Haliday, 1833 egg parasitoids of rice brown planthopper, *Nilaparvata lugens* (Stål, 1854) (Delphacidae). Chu & Hirashima (1981) summarized the earlier Taiwanese literature on the natural enemies of the rice leafhoppers and planthoppers, while Hirashima (1981) provided information on their survey in Taiwan. Unfortunately, almost no voucher specimens from these earlier studies in Taiwan could be found in the museum collections there, so with a few exceptions I was unable to verify their identity with confidence; it seems likely that most of them were misidentified at species level. Particularly, the voucher specimens of Miura *et al*. (1981) from Taiwan could not be located in the Kyushu University Museum (formerly in the Entomological Laboratory), Kyushu University, Hakozaki, Higashi-ku, Fukuoka, Japan (KUEC) (Dr. T. Mita, personal communication), so I was able to examine just a few specimens from that study which had been sent by Dr. T. Miura for identification to Dr. J. T. Huber to the Canadian National Collection of Insects, Arach-

nids and Nematodes, Ottawa, Ontario, Canada (CNC) (Triapitsyn & Berezovskiy 2004a). Per Dr. K. Kitamura (Shimane University, Matsue, Japan), Dr. Tadashi Miura's collection had been kept at his home but, according to his son Dr. Kazuki Miura, it was lost a long time ago (Dr. T. Mita, personal communication).

MATERIALS AND METHODS

Most specimens were identified during visits to TARI in August 2013 and October 2016. Additional material from Taiwan is deposited in the CNC (specimens had been sorted to genus by Dr. John T. Huber who generously loaned them to me) and the Entomology Research Museum, Department of Entomology, University of California, Riverside, California, USA (UCRC). All measurements (given in mm, as length or, for the wings, as length:width) and photographs were taken at UCRC from slide-mounted specimens using an Axioskop 2 Plus compound microscope (Carl Zeiss Microscopy, LLC., Thornwood, NY) and an Auto-Montage system (Syncroscopy, Cambridge, UK); the digital images were processed using Adobe Photoshop. Terminology for morphological features follows Gibson (1997). Abbreviations used are mps, multiporous plate sensillum or sensilla (longitudinal sensillum or sensilla, or sensory ridge or ridges) on the antennal flagellar segments, and F, funicular segment of the female antenna or flagellomere of the male antenna.

New records for Taiwan are marked by an asterisk (*).

AN ALPHABETICAL CHECKLIST OF THE TAIWANESE MYMARIDAE

*_**Acmopolynema berezovskiyi**_ **Triapitsyn, sp. nov.** (Figs. 1–7)

Type material. Holotype female (TARI) on slide (Fig. 1), labeled: 1. "CHINA: S.TAIWAN Kwei-tzu-chio Heng Chung 22–29. V.1965 KSLin"; 2. "TARI Mounted by V. V. Berezovskiy 2013 in Canada balsam"; 3. [magenta] "*Acmopolynema berezovskiyi* Triapitsyn HOLOTYPE ♀." The type locality is Kueitzuchiao, Hengchun, Kenting National Park, Pingtung Co., Taiwan. The holotype was remounted from a point; it is complete, dissected under 3 coverslips.

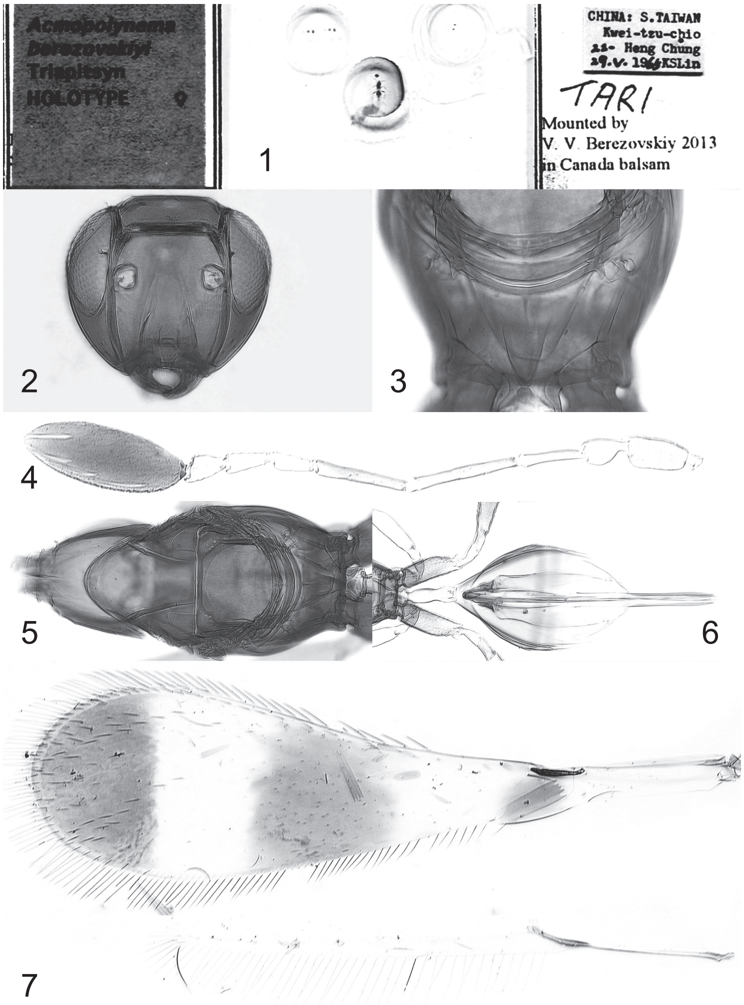
Description. Female (holotype). Body mostly brown except petiole and apical gastral terga light brown; scape and pedicel light brown; F1–F3 brown, F4–F6 pale yellowish, and clava dark brown; legs mostly brown except apical half or so of metafemur and metatibia and also apical tarsomeres dark brown, other tarsomeres light brown.

Head as in Fig. 2.

Antenna (Fig. 4). Scape with cross-ridges, 1.9 times as long as wide in lateral view (excluding radicle); pedicel shorter than F1; F2 longest funicular segment, F3 much longer than the following funicular segments; F4–F5 subequal in length, F6 the widest funicular segment; all funicular segments without mps; clava 2.7 times as long as wide, with 9 mps.

Mesosoma (Fig. 5) smooth. Pronotum mediolongitudinally subdivided only in its anterior half, with several pairs of short setae. Mesoscutum slightly wider than long, a little longer than scutellum. Axilla with 1 weak seta and 3 foveae along its margin with scutellum. Scutellum with a row of small frenal foveae; scutellar placoid sensilla close to anterior margin of scutellum. Propodeum (Fig. 3) with V-shaped submedian carinae not reaching its anterior margin, extending only to about 2/3 of its length, and with a very short, inconspicuous median carina at anterior margin only.

Fore wing (Fig. 7) 3.6 times as long as wide; marginal vein with 1 dorsal macrochaeta; longest marginal seta about 0.25 times maximum width of wing; disc with 3 brown bands: first band short and behind and a little beyond marginal vein, second band the widest and about in the middle of disc, and third band at wing's apex (extending to its apical mar-



Figs. 1–7. *Acmopolynema berezovskiyi*, female (holotype): 1. Slide; 2. Head in frontal view; 3. Propodeum; 4. Antenna; 5. Mesosoma; 6. Metasoma; 7. Fore and hind wings.

gin and occupying about 0.18 of wing's total length); approximately basal half of disc bare, the remainder of disc sparsely setose, with short modified setae of type F (Schauff 1981) mostly on the middle brown band and also a few on the hyaline area between the middle and apical brown bands, normal setae in apical 3/10 of disc, somewhat arranged in 3 irregular rows but more numerous at wing's apex. Hind wing (Fig. 7) 22.5 times as long as wide; disc hyaline, longest marginal seta 2.8 times maximum width of wing.

Protibia with 2 rows of 9 or 11 conical sensilla; metacoxa and metafemur with reticulate sculpture.

Metasoma (Fig. 6). Petiole shorter than metacoxa. Ovipositor occupying almost entire length of gaster, markedly exserted beyond its apex (by 0.35 times own total length), 1.7 times length of metatibia.

Measurements (mm). Mesosoma 0.683; mesoscutum: 0.24; scutellum: 0.184; petiole 0.203; gaster 0.768; ovipositor 1.076. Antenna: scape (excluding radicle) 0.107; pedicel 0.07; F1 0.097; F2 0.182; F3 0.158; F4 0.07; F5 0.07; F6 0.07; clava 0.273. Fore wing 1.47

: 0.403; longest marginal seta 0.1. Hind wing 1.168 : 0.052; longest marginal seta 0.147. Mesotibia: 0.455; metatibia: 0.627.

Male. Unknown.

Diagnosis. *A. berezovskiyi* is similar to the eastern Palaearctic and Oriental species *Acmopolynema tachikawai* Taguchi, 1971, described from Japan and also known from India, Malaysia, and Sri Lanka, to which it keys in Triapitsyn & Berezovskiy (2007). A modified couplet for that key to females of the Oriental and Australasian species of *Acmopolynema* is provided here to differentiate this new species from *A. tachikawai*, as follows.

1 Fore wing disc with a conspicuous apical dark band, occupying at most about 1/5 of wing's length and extending to its apical margin (as in Fig. 7) ··············· 1'

– Fore wing disc either hyaline or with different color patterns ······················ 2

1'(1) F2 and F3 notably darker than F1, F6 dark brown (Triapitsyn & Berezovskiy 2007, p. 10, Fig. 1); apical brown band on fore wing disc occupying about 0.13 of wing's total length ··························· ················· *A. tachikawai* Taguchi, 1971

– F2 and F3 concolorous with F1, F6 pale yellowish (Fig. 4); apical brown band on fore wing disc occupying about 0.18 of wing's total length ······························ ······················· *A. berezovskiyi*, sp. nov.

Etymology. The species is named after Mr. Vladimir Vasil'evich Berezovskiy (Laguna Hills, California, USA), fellow fairyfly taxonomist with special interest in the genus *Acmopolynema* Ogloblin, 1946 and a dedicated volunteer at the UCRC.

Hosts. Unknown.

Acmopolynema bimaculatum Subba Rao, 1989

A. bimaculatum Subba Rao: Triapitsyn and Berezovskiy, 2007: 22 (Pingtung Co.).

Material examined. Taiwan: Chiayi Co., Chiayi, 27.v.1970, K. S. Lin (1 female, TARI). Paomenszu (2 km S of Keelung), 11.x.1957, F. L. Ye (1 female, TARI). Pingtung Co., Pingtung, 10.iii.1970, K. S. Lin, in rice field (1 female, TARI). Taipei City: 15–30.ix.1963, K. S. Lin (2 females, TARI); 16–31.x.1963, K. S. Lin (1 female, TARI). Tsaoshan (20 km N of Taipei City): 5.x.1957, K. S. Lin (1 female, TARI); 28.x.1957, K. S. Lin (1 female, TARI).

**Acmopolynema indochinense* (Soyka, 1956)

Material examined. Taiwan: Pingtung Co., Kenting National Park, Hengchun, Kueitzuchiao (as "Kuraru, Heng Chung"), 22–29.v.1965, K. S. Lin (1 female, TARI). Taipei City: 1–12.vii.1963, K. S. Lin (1 female, TARI); viii.1963, K. S. Lin (2 females, TARI); iii.1970, K. S. Lin (1 female, TARI); x.1972, K. S. Lin (1 female, TARI).

Extralimital material examined. Brunei, Belait District, Rumah Teraja, 4°16.983'N 114°25.372'E, 40 m, 2.vii.2010, J. Mottern (1 female, UCRC). China, Guangdong, Cuangzhou, v.1983, Z. Bouček [1 female, Natural History Museum, London, England, UK (BMNH)]. Indonesia, Bali Island, Tabanan, Baturiti Candikuning, 25–27.viii.1999, M. I. Wibawa [2 females, R. M. Bohart Museum of Entomology, University of California, Davis, California, USA (UCDC)]. Thailand, Surat Thani, Sok River, N of Hwy 401, 8°54'26"N, 98°31'59"E, 20–21.ii.2005, D. Yanega (1 male, UCRC). Vietnam, Ho Chi Minh City (as Saigon), xi.1949, J. Barbier [1 female, Muséum national d'Histoire naturelle, Paris, France (MNHN)].

Comments. *A. indochinense* is newly recorded here from Brunei.

Acmopolynema longicoxillum Xu and Lin, 2002

A. longicoxillum Xu and Lin: Triapitsyn and Berezovskiy, 2007: 35 (Taipei).

Acmopolynema orchidea Triapitsyn and Berezovskiy, 2007

A. orchidea Triapitsyn and Berezovskiy, 2007: 31–32 [Orchid Island (Lan Yü)].

***Acmopolynema* spp.**

Material examined. Taiwan: Nantou Co., Ren'ai Township, Wushe, 1,150 m, 15.v.1983, H. Townes [1 male, American Entomological Institute, Gainesville, Florida, USA (AEI)]. Orchid Island (Lan Yü), 200 m, 5–9.vii.1991, C. K. Starr (1 female, CNC). Pingtung Co., Kenting National Park: Hengchun, Kueitzuchiao (as "Kuraru, Heng Chung"), 22–29.v.1965, K. S. Lin (1 female, 1 male, TARI); 230 m, 5–11.v.1991, C. K. Starr, S. M. Wu (3 males, CNC). Taipei City: Kuanyinshan (W of Taipei City), 5.x.1957, K. S. Lin (1 female, TARI); Tsaoshan (20 km N of Taipei City), 1.v.1955, K. S. Lin (1 male, TARI); 6–15.xii.1957, K. S. Lin (1 male, TARI); viii.1963, K. S. Lin (3 males, TARI).

***Alaptus immaturus* Perkins, 1905**

A. immaturus Perkins: Triapitsyn, 2017a: 35 ("Peishankeng", Taichung).

Hosts in Taiwan: undetermined Psocoptera on various plants (Triapitsyn 2017a).

***Alaptus* sp.**

Material examined. Taiwan, Nantou Co., Pilu-Chi Hydrological Station, ca. 24.23°N 121.3°E, ca. 2,300 m, 15–30.vi.1997, M. M. Yang (1 female, UCRC).

****Anagroidea marina* Triapitsyn and Berezovskiy, 2002** (Fig. 19)

Material examined. Taiwan, Taichung, Hsuchsan (above Shan Liu), Gieu Hut, 3,200 m, 8–10.v.1991, A. Smetana (2 females, CNC).

Extralimital material examined. China, Sichuan, 20 km N of Sabde, 29°35'N 102°23'E, "3,200 m" (according to Google Earth, the actual altitude at these coordinates is 2,488 m), 12–14.vii.1998 (3 females, CNC). Japan: Hokkaido Island, Hokkaido Prefecture, 20 km N of Akkeshi, Bekanbeushi Marsh, 100 m, 15.viii.1996, L. Masner (1 female, CNC). Honshu Island: Aichi Prefecture, Shitara, Uradani, 900 m, 27.vi–3.vii.1994, K. Yamagishi, beech forest (1 female, CNC). Iwate Prefecture, Kawai, Yoshibezawa, 1,050 m, 12–17.viii.1991, A. Smetana (1 female, CNC). Kyushu Island, Fukuoka Prefecture, Mt. Tachibana: 6–12.v.1979, K. Yamagishi (1 brachypterous female, CNC); 20.v–9.vi.1979, K. Yamagishi (1 female, CNC). Republic of Korea (South Korea), Kangwon-do, Pyengchang, Donam, Byungnae, 24.ix.1998, J.-Y. Choi (1 female, UCRC). Russia, Primorskiy kray, Ussuriyskiy rayon, Gornotayozhnoye, 12.vii.2000, M. V. Michailovskaya (1 male, UCRC).

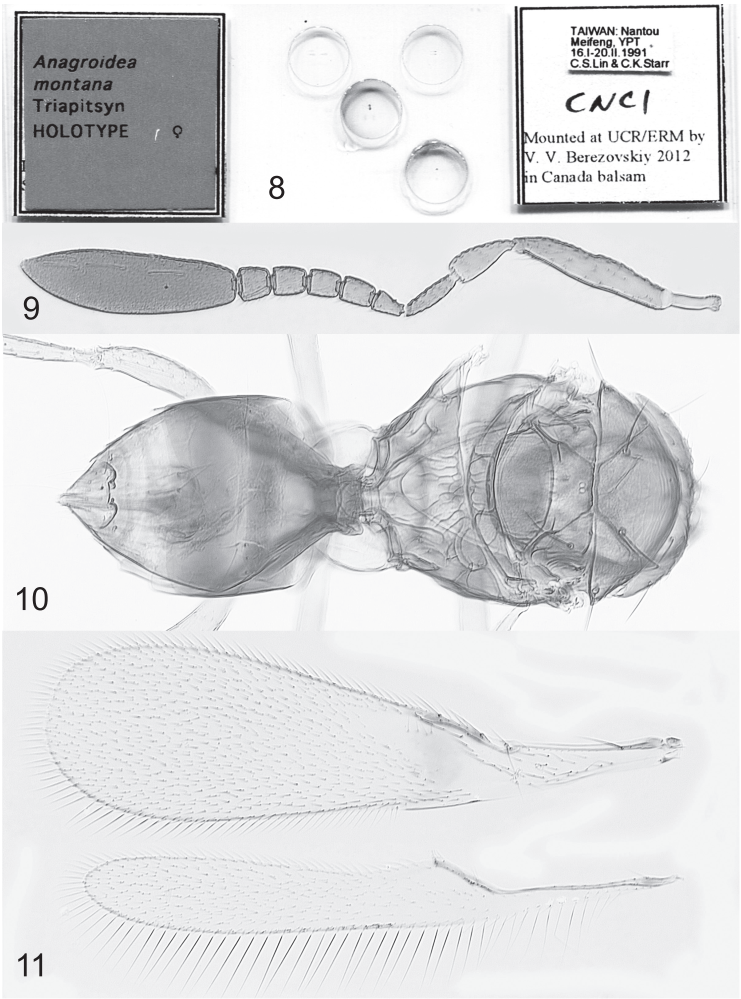
Comments. *A. marina* was recently reported from Tibet and Yunnan, China by Jin and Li (2016); it is newly recorded here from Japan and Republic of Korea.

****Anagroidea montana* Triapitsyn, sp. nov.** (Figs. 8–18)

Type material. Holotype female (CNC) on slide (Fig. 8), labeled: 1. "TAIWAN: Nantou Meifeng, YPT, 16.I-20.II.1991 S. C. Lin & C. K. Starr"; 2. "CNCI Mounted at UCR/ERM by V. V. Berezovskiy 2012 in Canada balsam"; 3. [magenta] "*Anagroidea montana* Triapitsyn HOLOTYPE ♀." The holotype is complete, dissected under 4 coverslips. Paratypes: Taiwan: Hualien Co., Tayuling, 12–15.ix.1980, K. S. Lin, C. H. Wang (1 female on point, TARI). Nantou Co.: "Forestry Station," 7.v.1997 (1 female on point, UCRC). Meifeng: 2,150 m, viii.1984, K. S. Lin, K. C. Chou (1 female on point, TARI); 16.i–20.ii.1991, S. C. Lin, C. K. Starr, yellow pan trap (1 male on slide, CNC).

Additional material examined. China, Beijing, Mentougou District, Xiaolongmen Station, 39°59.22'N 115°31.48'E, 1,095 m, 28.vii.2002, G. Melika (1 female, UCRC). This non-type, extralimital, dry-mounted specimen is more similar in color to *A. montana* than to *A. marina*, so it is provisionally identified as the former species.

Description. Female (holotype). Body mostly brown except trabeculae and petiole dark brown; radicle light brown and remainder of antenna brown; legs mostly light brown ex-



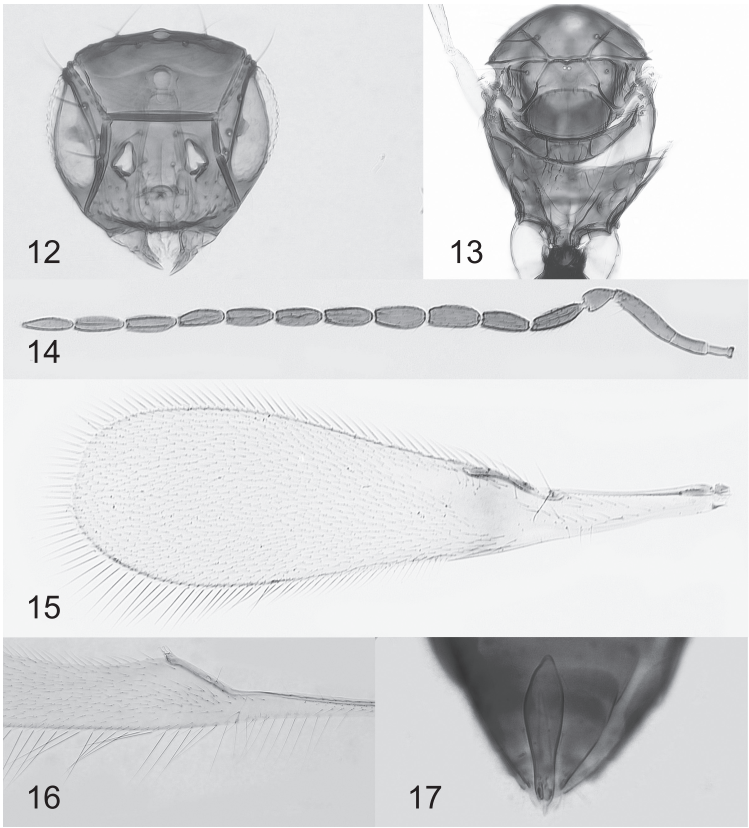
Figs. 8–11. *Anagroidea montana*, female (holotype): 8. Slide; 9. Antenna; 10. Mesosoma and metasoma; 11. Fore and hind wings.

cept meso- and metacoxa notably lighter.

Head (Fig. 12) with transverse trabecula slightly above mid level of eyes. Vertex transversely striate, face almost smooth; toruli slightly above lower level of eyes. Mandible bidentate, its length about 0.2 times of head height.

Antenna (Fig. 9) with radicle narrow and smooth, remainder of scape 5.1 times as long as wide and faintly sculptured; pedicel slightly longer than F1 (the longest funicular segment); F2–F6 subequal in length (F2 the shortest and narrowest among them), F1 much longer than wide, F2 longer than wide, F3–F5 slightly longer than wide, and F6 slightly wider than long; F1 and F2 without mps, F3–F6 apparently each with 2 mps; clava 3.4 times as long as wide, with 7 mps, almost as long as funicle.

Mesosoma (Fig. 10) with pronotum faintly sculptured, narrow medially in dorsal view and with several strong setae. Mesoscutum with reticulate sculpture in anterior half or so and with less conspicuous, faint cell-like sculpture in posterior half or so, with a pair of strong adnotaular setae and a strong seta at posterolateral angle. Axilla faintly sculptured, with a



Figs. 12–17. *Anagroidea montana*: 12. Female head in frontal view (holotype); 13. Male mesosoma (paratype); 14. Male antenna (paratype); 15. Male fore wing (paratype); 16. Base of male hind wing (paratype); 17. Male genitalia (paratype).

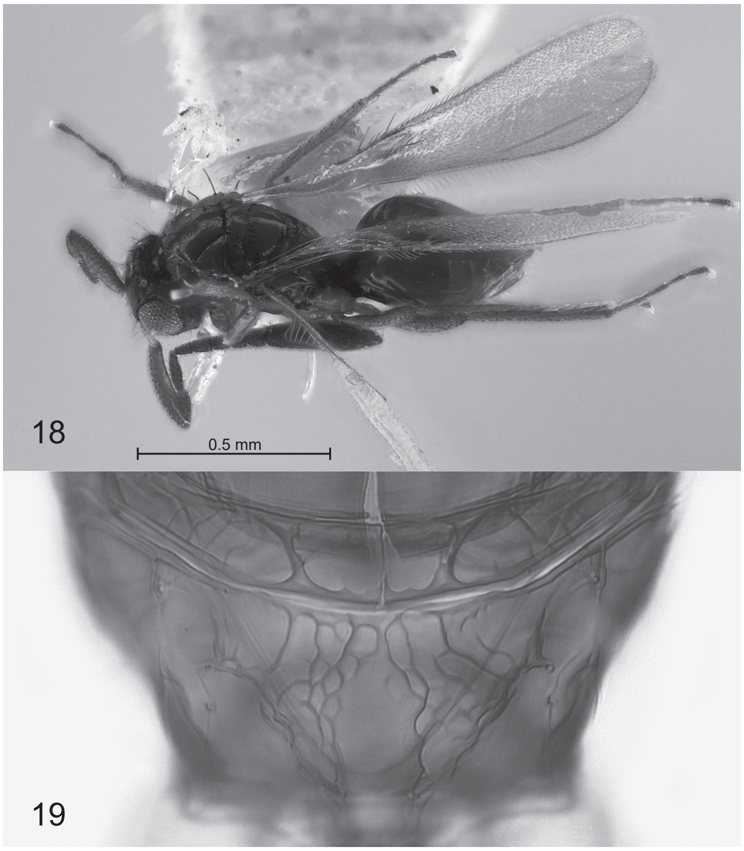
very strong seta. Scutellum faintly sculptured, a little longer than mesoscutum, frenal line with a row of large but inconspicuous foveae; scutellar placoid sensilla very close to anterior margin and touching each other. Dorsellum reticulate. Propodeum with a pattern of submedian carinae and reticulate sculpture (mainly medially at its anterior margin), and with one pair of weak setae mediolaterally. Propodeal spiracle small. Mesophragma broadly U-shaped, not reaching posterior margin of propodeum.

Fore wing (Fig. 11) 3.5 times as long as wide; disc faintly infuscate throughout (brownish), more so behind marginal vein; base of disc with a large bare area behind and partially beyond marginal and stigmal veins, and apical half of disc densely setose; longest marginal seta about 0.25 times maximum width of wing. Hind wing (Fig. 11) 7.8 times as long as wide; disc slightly infuscate and densely, more or less uniformly, setose beyond venation, with about 12–13 irregular rows of setae in the broadest part; longest marginal seta about 1.0 times maximum width of wing.

Coxae faintly reticulate.

Metasoma (Fig. 10). Petiole about 3 times as wide as long. Gaster shorter than mesosoma; first gastral tergum and first gastral sternum with sclerotized ridges and carinae; ovipositor short, occupying about half of gaster length, not exserted beyond gastral apex, about 0.6 times length of metatibia.

Measurements of the holotype (mm). Mesosoma 0.344; mesoscutum: 0.088; scutellum: 0.102; petiole 0.022; gaster 0.283; ovipositor 0.142. Antenna: scape (excluding radicle) 0.172;



Figs. 18–19. *Anagroidea* spp.: 18. *Anagroidea montana*, female habitus in dorsolateral view (paratype, Forestry Station, Nantou Co., Taiwan); 19. *Anagroidea marina*, female propodeum (Gornotayozhnoye, Primorskiy kray, Russia).

pedicel 0.07; F1 0.06; F2 0.03; F3 0.036; F4 0.033; F5 0.036; F6 0.035; clava 0.228. Fore wing 0.833 : 0.237; longest marginal seta 0.06. Hind wing 0.8 : 0.102; longest marginal seta 0.1. Mesotibia: 0.23; metatibia: 0.245.

Variation (dry-mounted paratype from "Forestry Station" in Nantou Co.). Body length 0.99 mm. Clava only a little darker than funicle; gaster more or less concolorous with head and mesosoma (brown).

Male (paratype). Similar to female except for the normal sexually dimorphic features such as antenna and genitalia, and the following. Head with less pronounced, rather faint sculpture on vertex and face. Antenna (Fig. 14) brown, longer than body, with scape about 6 times as long as wide, slightly longitudinally striate; flagellomeres roughly subequal in length (F1 the longest), longer than wide, each with several mps. Mesosoma (Fig. 13) less sculptured than in female. Fore wing (Fig. 15) 3.6 times as long as wide; longest marginal seta 3.8 times maximum wing width. Hind wing (Fig. 16) 8.5 times as long as wide; longest marginal seta 1.1 times maximum width of wing. Gaster almost entirely dark brown. Genitalia (Fig. 17) length 0.133 mm.

Diagnosis. The new species keys to couplet 4 in Triapitsyn & Berezovskiy (2002), together with *A. marina* and *Anagroidea himalayana* (Mani and Saraswat, 1973). A modified couplet for their key is therefore is given below, which applies to females only. In addition to the characters mentioned in it, female *A. montana* differs from that of *A. marina*, to which it is most similar, in the relatively light-

er color of the funicle, which is light brown to brown and contrastingly lighter than the clava.

4(3) Base of fore wing disc with a well-defined row of 6 or 7 setae very close to submarginal vein (Triapitsyn & Berezovskiy 2002, p. 5, Fig. 5) ··················*A. himalayana* Mani and Saraswat, 1973

– Base of fore wing disc with several setae only between submarginal vein and the long submedian row of setae (Triapitsyn & Berezovskiy 2002, p.9, Figs. 9 and 11) ·· 5

5(4) Head and mesosoma dark brown; F1 slightly longer than (or at most about as long as) pedicel; propodeum sculptured as in Fig. 19 ···*A. marina* Triapitsyn and Berezovskiy, 2002

– Head and mesosoma brown (Fig. 18); F1 slightly shorter than pedicel; propodeum sculptured as in Fig. 10 ··· *A. montana*, sp. nov.

Etymology. The species name is an adjective referring to its occurrence in the mountains.

Hosts. Unknown.

Comments. The following specimens of *A. himalayana* were examined: Nepal: Bagmati Zone, Phulchowki (also spelled as Phulcoki or Phulchoki), 2,600 m, 13.x.1983, A. Smetana, screen sweeping in old oak forest (1 female, CNC). Dhawalagiri (Dhaulagiri) Zone, Goropani Pass (also spelled as Ghoropani, Gorepani, or Ghorepani), 2,850 m, 5.x.1983, A. Smetana, screen sweeping (1 female, CNC). Langtang, 1,950 m, 13.iv.1985 (1 female, CNC). This species is newly recorded from Nepal.

***Anagrus (Anagrella) sp.**

Material examined. Taiwan, Pingtung Co., Kenting National Park, 210 m, 11–17.v.1991, C. K. Starr, S. M. Wu, pan trap in secondary forest (1 female, CNC).

Comments. This specimen, which possibly represents an undescribed species, is similar to *Anagrus* (*Anagrella*) *albiclava* Chiappini and Lin, 1998 in having a white clava of the female antenna, from which it differs by presence of an incomplete row of setae in the middle of the fore wing disc (absent in *A. albiclava*).

***Anagrus* (*Anagrus*) *frequens* Perkins, 1905**

?*Anagrus flaveolus* Perkins Waterhouse, 1913: Chen and Yu, 1989: 460–461 (illustration of a female antenna, key).

A. (*Anagrus*) *frequens* Perkins: Triapitsyn and Beardsley, 2000: 33 (no locality data except "Formosa").

Material examined. Taiwan: Taipei City, City Park, 19.xii.1990–8.i.1991, J. T. Chao (1 female, CNC). Taichung, Wufeng, TARI, 24°01'52.4"N 120°41'34.2"E, 76 m: 5–7.x.2016, S. V. Triapitsyn, yellow pan traps in wild rice field (1 female, UCRC); 6–11.x.2016, S. V. Triapitsyn, H.-T. Shih, Malaise trap in wild rice field (3 females, UCRC).

Host in Taiwan. *Perkinsiella* sp. (Delphacidae) (Triapitsyn & Beardsley 2000).

Comments. The female antenna illustrated by Chen & Yu (1989, p. 460, Fig. 11) under "*A. flaveolus*" definitely belongs to a species from the *atomus* species group of the nominate subgenus of *Anagrus* and fits those specimens of *A. frequens* that lack mps on F3; indeed, among the three specimens recently collected in the wild rice field at TARI, one female has a mps on F3 on both antennae, one only on one antenna, and one lacks mps on both antennae.

***Anagrus* (*Anagrus*) *nilaparvatae* Pang and Wang, 1985**

?*Anagrus* sp.: Lin 1974: 93–96 [Pingtung, Taipei; key, illustration of a fore wing (consistent with that of *A. nilaparvatae*)], 99 (descriptive notes and history of previous records and misidentifications in Taiwan).

A. incarnatus Haliday, 1833: Chen and Yu, 1989: 459–461 (Pingtung, Taichung, Taipei; illustrations, key); Chen, 1993:

267–273 (Changhua Co., Chiayi Co., Nantou Co., Taichung); Chiappini *et al.*, 1996: 560 (indicated probable misidentifications).

?*Anagrus flaveolus* Waterhouse, 1913: Chu and Hirashima, 1981: 35–36; Sahad and Hirashima, 1984: 57 (Chiayi Co.); Chiappini *et al.*, 1996: 586 (indicated previous misidentifications).

A. (*Anagrus*) *nilaparvatae* Pang and Wang: Triapitsyn and Berezovskiy, 2004a: 21 ("Antei").

Material examined. Taiwan, Taichung, Wufeng, TARI, 24°01'52.4"N 120°41'34.2"E, 76 m: 5–7.x.2016, S. V. Triapitsyn, yellow pan traps in wild rice field (1 female, UCRC); 6–11.x.2016, S. V. Triapitsyn, H.-T. Shih, Malaise trap in wild rice field (5 females, UCRC).

Hosts in Taiwan. *Laodelphax striatella* (Fallén, 1826) (Chen 1993) and *N. lugens* (Stål, 1854) (Delphacidae) (Lin 1974; Chu & Hirashima 1981; Chen & Yu 1989; Chen 1993; Triapitsyn & Berezovskiy 2004a), as well as *Nephotettix cincticeps* (Uhler, 1896) (Cicadellidae) (Lin 1974; Chu & Hirashima 1981).

Comments. It is possible that *Anagrus* sp. mentioned by Lin (1974) was a complex of several species although most likely the bulk of those were *A. nilaparvatae*, but I could not locate any of his specimens identified as such in TARI to verify that; in fact, I could not find any specimens of *Anagrus* there despite conducting thorough searches both in 2013 and 2016. It is also possible that these had been borrowed by Dr. Bing-huei Chen during preparation of his publication with the redescription of *A. incarnatus* from Taiwan (Chen & Yu 1989) and then never returned to the collection so after his retirement these got lost (or misplaced) somehow. Their detailed illustrations of the latter species, combined with a redescription (which is not without some mistakes), leave little doubt that they dealt with *A. nilaparvatae*.

As indicated by Triapitsyn & Berezovskiy (2004a, p. 21), *A. incarnatus* of Sahad and Hirashima, 1984: 46–50 definitely belongs to *A. nilaparvatae* [also see discussion in Triapitsyn & Berezovskiy (2004a) and Triapitsyn (2013c, 2015b)] while *A. flaveolus* of Sahad and Hirashima, 1984: 55–58 likely belongs to those specimens of *A. nilaparvatae* that are lacking a mps on F3 of the female antenna. Without access to their missing voucher specimens, the identity of *A. nigriventris* Girault, 1911 of Sahad and Hirashima, 1984: 52–55 from Japan and Republic of Korea remains unclear; it is definitely not the true *A. nigriventris* which is a New World species also known from the Hawaiian Islands (Triapitsyn 2015b) because according to the illustration in Sahad & Hirashima (1984: 54, their Fig. 18B), their "*A. nigriventris*" lacks adnotaular setae on the midlobe of the mesoscutum which are always present in the true *A. nigriventris*. Thus their species belongs to the very difficult *A. incarnatus* complex of *Anagrus* discussed by Triapitsyn & Berezovskiy (2004a) and Triapitsyn (2015b).

Anagrus (*Anagrus*) *setosus* Chiappini and Lin, 1998

A. (*Anagrus*) *setosus* Chiappini and Lin: Triapitsyn and Berezovskiy, 2004a: 9 (Nantou Co.).

Anagrus (*Anagrus*) sp.

Material examined. Taiwan, Taichung, Wufeng, TARI, 24°01'52.4"N 120°41'34.2"E, 76 m, 6–11.x.2016, S. V. Triapitsyn, H.-T. Shih, Malaise trap in wild rice field (1 female, UCRC).

Comments. This interesting specimen, which likely represents an undescribed species, belongs to the *A. brocheri* Schulz, 1910 complex of the *incarnatus* species group of the nominate subgenus of *Anagrus* (Triapitsyn 2015b) and is most similar to (and yet different from in the fore wing chaetotaxy) *A.* (*Anagrus*) *insularis* Dozier, 1936, which is known from the Hawaiian Islands (Triapitsyn & Beardsley 2000).

***Anagrus* (*Paranagrus*) *optabilis* (Perkins, 1905)**

A. (*Paranagrus*) *optabilis* (Perkins): Miura *et al*., 1981: 44–49 (Taipei and numerous localities in central and southern Taiwan); Sahad and Hirashima, 1984: 68 (Chiasien, Chiayi Co., Tainan); Chen and Yu, 1989: 460–461 (illustration, key); Chiappini *et al*., 1996: 556; Triapitsyn and Beardsley, 2000: 29 (no locality data except "Formosa"); Triapitsyn and Berezovskiy, 2004a: 7 ("Antei").

Hosts in Taiwan. *L. striatella* (Fallén, 1826) (Miura *et al.* 1981), *N. lugens* (Stål, 1854) (Miura *et al.* 1981; Triapitsyn & Berezovskiy 2004a), *Perkinsiella* sp. (Triapitsyn & Beardsley 2000), and *Sogatella furcifera* (Horváth, 1899) (Miura *et al.* 1981) (Delphacidae).

***Anaphes nipponicus* Kuwayama, 1932**

A. *nipponicus* Kuwayama: Thompson, 1958: 568 (record needs confirmation).

***Anaphes* spp.**

Material examined. Taiwan, Nantou Co.: "Forestry Station," 7.v.1997 (2 males, UCRC). Pilu-Chi Hydrological Station, ca. 24.23°N 121.3°E, ca. 2,300 m, 15–30.vi.1997, M. M. Yang (3 females, UCRC).

Comments. The earlier reports of *Anaphes* sp. from Taiwan from eggs of *N. cincticeps* and *N. lugens*, summarized by Chu & Hirashima (1981), are without any doubt erroneous host records because species of the genus *Anaphes* Haliday, 1833 do not parasitize eggs of either Cicadellidae or Delphacidae.

The examined specimens from Nantou Co. belong to two different species: the females have a much wider fore wing than the males.

***Arescon sparsiciliatus* Jin and Li, 2016**

A. ?*sparsiciliatus* Jin and Li: Triapitsyn, 2016: 146 (Nantou Co.).

Material examined. Taiwan: Taichung, Wufeng, TARI, 24°01'52.4"N 120°41'34.2"E, 76 m, 6–11.x.2016, S. V. Triapitsyn, H.-T. Shih, Malaise trap in wild rice field (1 female, UCRC). Taipei City, viii.1963, K. S. Lin (1 male, TARI).

***Arescon* spp.**

Material examined. Taiwan: Orchid Island (Lan Yü), 200 m, 5–9.vii.1991, C. K. Starr (1 male, CNC). Taichung, Wufeng, TARI, 24°01'52.4"N 120°41'34.2"E, 76 m, 6–11.x.2016, S. V. Triapitsyn, H.-T. Shih, Malaise trap in wild rice field (1 male, UCRC).

****Australomymar* ?*gressitti* (Doutt, 1955)**

Material examined. Taiwan, Pingtung Co., Kenting National Park, 5–8.iv.1991, C. K. Starr, S. M. Wu (1 female, CNC, determined by J. T. Huber).

Comments. Indeed, this specimen fits the original description of *A. gressitti* in most aspects except the exserted part of the ovipositor seems to be relatively longer, about 0.4 mm and about the same length as gaster, whereas in the holotype of this species from Tol Island [Chuuk (Truk) Islands, Caroline Islands, Chuuk (Truk) State, Federated States of Micronesia] the exserted part of the ovipositor is 0.28 mm and about the same length as mesosoma (Doutt 1955).

****Australomymar* spp.**

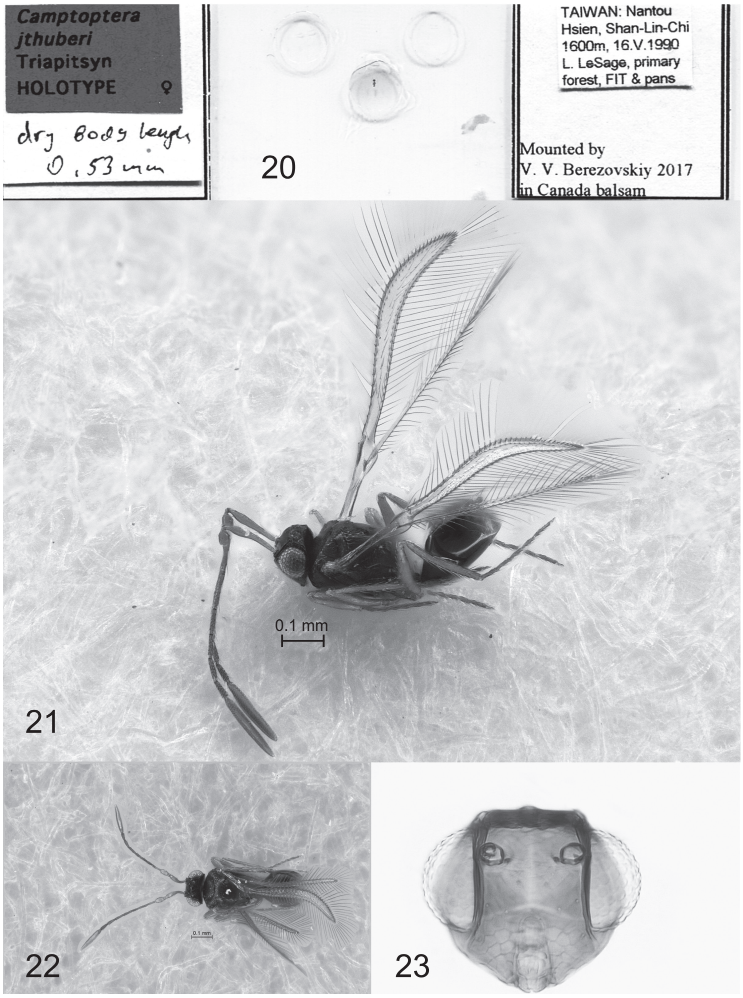
Material examined. Taiwan: Nantou Co.: Meifeng, 2,130 m, 10–17.vii.1993, A. Smetana (1 female, CNC). Sun Moon Lake, Tehuache, 800–900 m, 6.vi.1990, J. M. Heraty (1 male, CNC). Zhushan, Shan Lin Xi, 1,600 m, 16.v.1990, L. LeSage (3 females, 2 males, CNC). Pingtung Co., Tengchih, Medium Altitude Experimental Station, 23°05.75'N 120°47.37'E, 1,660 m, L. Masner: 3–5.vi.2008 (1 female, 1 male, CNC); 4.vi.2008 (2 males, CNC); 7–9.vi.2008 (1 female, CNC).

Comments. These specimens were identified as belonging to this genus by Dr. J. T. Huber. Most of those from Nantou Co. have two transverse brownish bands on the fore wing disc in both sexes and thus seem to be somewhat similar to *A. vietnamicum* Narendran and

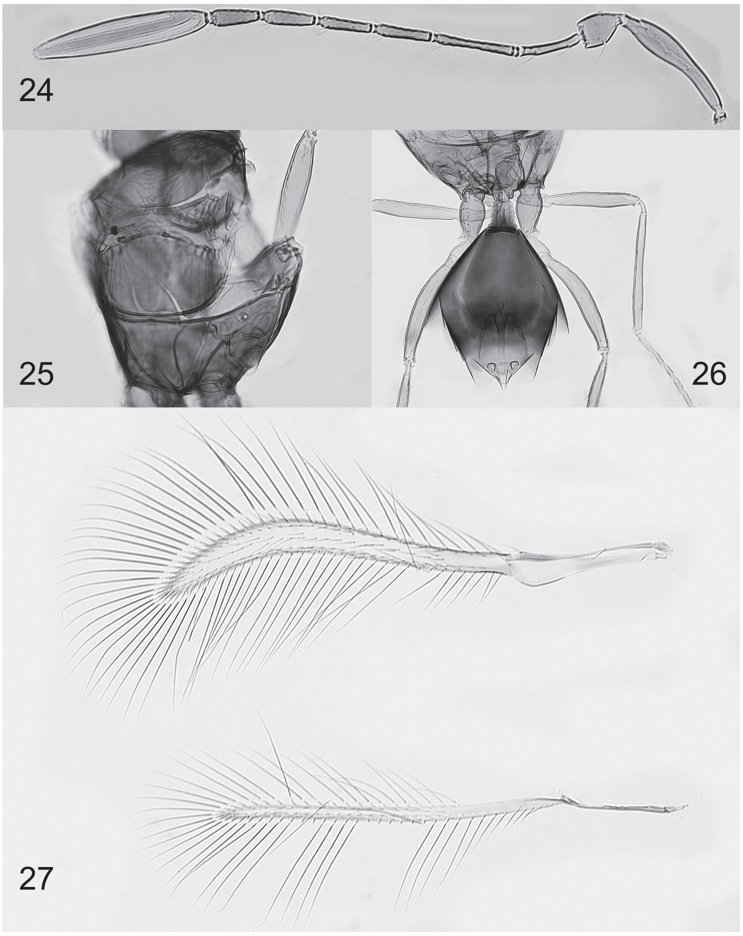
Anjana, 2013 from Vietnam which also has this feature, particularly in female sex; clava of the female antenna is white. Unfortunately, the antennae of the single known female of the latter species (the holotype) are incomplete (Narendran & Anjana 2013), so the color of its clava is unknown. The other specimens from Taiwan likely belong to two undescribed species.

Camptoptera jthuberi* **Triapitsyn, sp. nov. (Figs. 20–30)

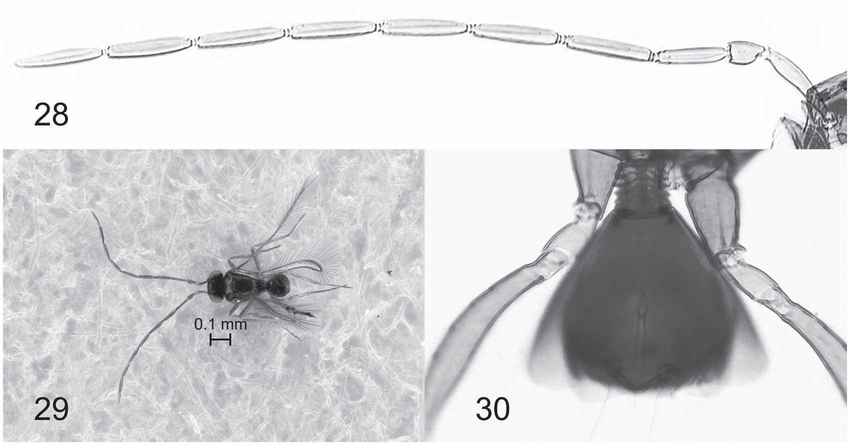
Type material. Holotype female (CNC) on slide (Fig. 20), labeled: 1. "TAIWAN: Nantou Hsien, Shan-Lin-Chi 1,600m, 16.V.1990 L. LeSage, primary forest, FIT & pans"; 2. "CNC Mounted by V. V. Berezovskiy 2017 in Canada balsam"; 3. [magenta] "*Camptoptera jthuberi* Triapitsyn HOLOTYPE ♀." The type locality is Shan Lin Xi, Zhushan, in Nantou Co. The holotype (Fig. 21) was remounted from a card; it is almost complete (missing one fore leg) and dissected under 3 coverslips. Paratypes: Taiwan: Kaohsiung City, Shanping, 640 m, 11–20. iv.1988, R. L. Davidson, J. E. Rawlins, C. W. Young, pan traps (1 male on card and 1 male



Figs. 20–23. *Camptoptera jthuberi*, female: 20. Slide (holotype); 21. Habitus in dorsolateral view (dry-mounted holotype prior to being slide-mounted); 22. Habitus in dorsal view (paratype, Shan Lin Xi, Zhushan, Nantou Co., Taiwan); 23. Head in frontal view (holotype).



Figs. 24–27. *Camptoptera jthuberi*, female: 24. Antenna (holotype); 25. Mesosoma (paratype, Shan Lin Xi, Zhushan, Nantou Co., Taiwan); 26. Propodeum and metasoma (holotype); 27. Fore and hind wings (holotype).



Figs. 28–30. *Camptoptera jthuberi*, male (paratype, Wushe, Nantou Co., Taiwan): 28. Antenna; 29. Habitus in dorsal view (prior to being slide-mounted); 30. Metasoma.

on slide, CNC). Nantou Co.: Meifeng, 2,150 m, 19.ii–18.viii.1991, C. K. Starr, C. S. Lin, pan traps (2 females on cards and 1 female on slide, CNC). Wushe, 1,100 m, 27.v.1990, J. M. Heraty, deciduous forest, H074 [collector's code] (1 male on card, CNC). Zhushan, Shan Lin Xi [as Shan-Lin-Chi], 1,600 m, 16.v.1990, L. LeSage, primary forest, flight intercept trap and pan traps (4 females on cards, 2 females on points, and 1 female on slide, CNC; 1 female on slide, UCRC).

Description. Female (holotype). Body (Fig. 21) dark brown (mesosoma slightly lighter than head or metasoma); scape, pedicel and clava light brown, funicle brown except base of F1 light brown; legs mostly light brown except metatibia a little darker (mostly brown).

Head (Fig. 23). Face with faint cell-like sculpture, more conspicuous below lower level of eyes and above toruli, vertex with a more reticulate sculpture, and occiput striate.

Antenna (Fig. 24) with scape minus short radicle 5.6 times as long as wide; pedicel shorter than F1; funicle 7-segmented (F2 ring-like), F1 shorter than F3 (the longest funicular segment), slightly longer than F4–F6 and longer than F7 (the widest funicular segment), ratios of F3 length to F1 length and F3 length to F4 length 1.4; clava 5.5 times as long as wide, with 4 very long mps, a little longer than combined length of F5–F7.

Mesosoma (as in Fig. 25). Mesoscutum reticulate, with notauli short, incomplete (only at its anterior margin); scutellum notably longitudinally striate on the sides and with a faint, inconspicuous cell-like sculpture medially. Propodeum with very strong, wide apart, complete (extending to propodeal anterior margin) submedian ridges and an incomplete lateral carina originating at an angle to each submedian ridge (not extending to propodeal anterior margin), but otherwise mostly hardly sculptured.

Fore wing (Fig. 27) 13.9 times as long as wide, curving strongly towards wing's apex; longest marginal seta 4.4 times maximum wing width; disc with a rather strong brownish tinge and 1 (in smaller specimens) or 2 (in larger specimens) irregular median rows of setae besides adnotaular rows of setae. Hind wing (Fig. 27) about 29 times as long as wide; disc slightly infumate, with 2 rows of setae besides admarginal rows of setae; longest marginal seta 8.8 times maximum wing width.

Gaster (Fig. 26) shorter than mesosoma. Petiole (Fig. 26) 1.1 times wider than long, shorter than metacoxa, strongly ridged and without a lateral lamella. Ovipositor barely exserted beyond apex of gaster, occupying 0.45 of its length, and 0.6 times length of metatibia.

Measurements of the holotype (mm). Body (of the dry-mounted, critical point dried specimen prior to slide-mounting) 0.53; head (of the dry-mounted specimen prior to slide-mounting) 0.099; mesosoma 0.303; petiole 0.052; gaster 0.267; ovipositor 0.128. Antenna: scape plus radicle 0.142; pedicel 0.043; F1 0.06; F2 0.003; F3 0.083; F4 0.058; F5 0.055; F6 0.052; F7 0.049; clava 0.183. Fore wing 0.763 : 0.055; longest marginal seta 0.242. Hind wing 0.707 : 0.024; longest marginal seta 0.212. Metatibia: 0.215.

Variation (paratypes, as in Fig. 22). Body length of the dry-mounted, critical point dried specimens 0.445–0.595 mm. Antenna with scape minus radicle 5.5–7.1 times as long as wide; ratio of F3 length to F1 length 1.35–1.4; clava 5.0–5.1 times as long as wide. Submedian ridges on propodeum sometimes not extending to propodeal anterior margin (almost reaching it). Fore wing 13.8–16.7 times as long as wide, longest marginal seta 3.9–4.8 times maximum wing width. Hind wing 28–29 times as long as wide, longest marginal seta 7.9–8.1 times maximum wing width. Ovipositor 0.5–0.6 times length of metatibia.

Male (paratypes). Body length (of the card-mounted, critical point dried specimens) 0.41–0.53 mm. Similar to female except for the normal sexually dimorphic features such as antenna and genitalia. Body (Fig. 29) entirely dark brown, antenna and legs brown. Antenna (Fig. 28) with flagellum 10-segmented (F2 and

F4 ringlike, very short and thus inconspicuous, other flagellomeres much longer than wide and about as long as scape except F1 a little shorter than scape), scape about 5.2 times as long as wide. Mesosoma much longer than metasoma. Fore wing 15.3 times as long as wide. Genitalia (Fig. 30) length 0.07 mm.

Diagnosis. *C. jthuberi* probably does not belong to the informal *cardui* species group of *Camptoptera* Foerster, 1856, as defined by Triapitsyn (2014b), even though it somewhat resembles some of its members. It differs from the only described Oriental species from this group, *C. kannada* Subba Rao, 1989 from India (Triapitsyn 2017b), and also from the western Palaearctic and Nearctic species *C. cardui* (Foerster, 1856) and the eastern Palaearctic species *C. zagvozdka* Triapitsyn, 2014 in having very strong, wide apart, complete submedian ridges on the propodeum which are easily visible even on dry-mounted specimens (the propodeum is without any ridges or defined submedian carinae in *C. kannada* and *C. zagvozdka*, and with faint, often almost indistinct, wide apart linear submedian carinae slightly narrowing towards the metanotum but not extending to it in *C. cardui*). The new species also has a strongly ridged petiole, thus being similar to the rather common Oriental and Eastern Palaearctic species *C. matcheta* Subba Rao, 1989, from which it differs in having a much longer flagellum of the female antenna and a narrower, less setose fore wing (Triapitsyn 2017b). Rather, *C. jthuberi* is most similar to *C. concava* Taguchi, 1972, described from Bohol Island, the Philippines (Taguchi 1972). Unfortunately, the single known specimen of the latter species, the holotype female, is lost. Female of *C. jthuberi* differs from that of *C. concava* mainly in the proportions of some funicle segments, particularly in having F3 notably longer than F1 (at least 1.35 times) whereas in *C. concava* F1 is almost the same length as F3 (F3 1.08 times length of F1), as illustrated by Taguchi (1972) and also calculated from the measurements provided in its original description.

Etymology. The species is named after Dr. John T. Huber (CNC) who identified specimens of the type series to genus and kindly let me borrow them.

Hosts. Unknown.

***Camptoptera matcheta* Subba Rao, 1989**

Material examined. Taiwan, Nantou Co.: Meifeng, 2,130 m, 10–17.vii.1993, A. Smetana (1 female, CNC). Zhushan, Shan Lin Xi, 1,600 m, 16.v.1990, L. LeSage (1 female, CNC).

***Camptoptera sakaii* Taguchi, 1977**

C. sakaii Taguchi, 1977b: 143–144 (Kenting National Park, Pingtung Co.; holotype female lost from EUMJ).

Comments. Female of this species was recently redescribed by Rehmat & Anis (2014) based on specimens from India. However, its true identity can only be revealed when a well matching female is collected at or near the type locality and designated as a neotype. Although its original description has good illustrations of the female antenna and mesosoma, unfortunately Taguchi (1977b) did not provide a detailed illustration or description of fore wing disc chaetotaxy, which may be important for recognition of *C. sakaii*.

***Camptoptera stoptera* Triapitsyn, 2014**

C. stoptera Triapitsyn, 2014b: 73 (Nantou Co.).

Material examined. Taiwan, Nantou Co., Lienhuatse, 750 m, 20.ii–18.iii.1991, C. K. Starr, C. S. Lin (1 female, CNC).

***Camptoptera taiwana* Taguchi, 1977**

C. taiwana Taguchi 1977b: 144–145 (Kenting National Park, Pingtung Co.; holotype female lost from EUMJ).

***Camptoptera* spp.**

Material examined. Taiwan: Nantou Co.: Lienhuatse, 750 m, 20.ii–18.iii.1991, C. K. Starr, C. S. Lin (1 female, CNC). Meifeng,

16.i–20.ii.1991, C. S. Lin, C. K. Starr (2 females, CNC). Orchid Island (Lan Yü), 200 m, 5–9.vii.1991, C. K. Starr (1 female, CNC). Pingtung Co., Kenting National Park, C. K. Starr, S. M. Wu: 5–8.iv.1991 (5 females, 1 male, CNC); 210–230 m, 5.v.1991 (4 males, CNC); 210 m, 11–17.v.1991 (1 male, CNC).

Comments. Five of the six males from the Kenting National Park belong to the group of species which corresponds to the former genus *Eomymar* Perkins, 1912, in which only F2 is ring-like while F4 is about as long as F3 or F5 (Triapitsyn 2014b), and the five females from there belong to three different, undetermined morphospecies none of which, unfortunately, matches well the original descriptions and illustrations of either *C. sakaii* or *C. taiwana*.

***_Camptopteroides_ sp(p). (Fig. 31)**

Material examined. Taiwan: Kaohsiung City, Shanping, 640 m, 1–10.iv.1988, R. L. Davidson, J. E. Rawlins, C. W. Young (1 female, CNC). Nantou Co., Zhushan, Shan Lin Xi, 1600 m, 16.v.1990, L. LeSage (1 female, CNC).

Comments. Both females were identified as members of the genus *Camptopteroides* Viggiani, 1974 by Dr. J. T. Huber. The macropterous specimen from Kaohsiung City is not *C. alata* Lin, 1999 because it has a banded fore wing, and that from Nantou Co. is strongly brachypterous (Fig. 31).

***_Cleruchus_ spp.**

Material examined. Taiwan: Nantou Co., Zhushan, Shan Lin Xi, 1,600 m, 16.v.1990, L. LeSage (1 female, CNC). Pingtung Co., Tengchih, Medium Altitude Experimental Station, 23°05.75’N 120°47.37’E, 1,660 m, 4.vi.2008, L. Masner (1 female, CNC). Taichung, Anmashan, 2,230 m, 11–15.v.1992, A. Smetana (1 female, CNC).

Comments. These specimens were identified as members of the genus *Cleruchus* Enock, 1909 by Dr. J. T. Huber. The females from Nantou Co. and Taichung belong to a different species than the female from Pingtung Co.

***_Cosmocomoidea atra_ Foerster, 1841**

Material examined. Taiwan: Pingtung Co., Kenting National Park, Hengchun, Kueitzuchiao (as “Kuraru, Heng Chung”), 22–29.v.1965, K. S. Lin (8 females, TARI). Taichung, Shengkuang, 1,850 m, 20.ix.1968, K. S. Lin (1 female, TARI). Taipei City: 6–15.xii.1957, K. S. Lin (1 female, TARI); 13–17.v.1963, K. S. Lin (1 female, TARI); viii.1963, K. S. Lin (1 female, TARI); 9–25.i.1964, K. S. Lin (1 female, TARI); 1–19.ii.1964, K. S. Lin (1

Fig. 31. *Camptopteroides* sp., brachypterous female (Shan Lin Xi, Zhushan, Nantou Co., Taiwan): habitus in dorsal view.

female, TARI); 11–21.iv.1964, K. S. Lin (1 female, TARI).

***Cosmocomoidea kikimora* Triapitsyn, 2013**

Material examined. Taiwan, Taipei City: Hsintien, 31.iii.1963, K. S. Lin (2 females, TARI); 1–12.vii.1963, K. S. Lin (1 female, TARI); 4–19.xi.1963, K. S. Lin (2 females, TARI); 20–30.xii.1963, K. S. Lin (1 female, TARI); 9–18.i.1964, K. S. Lin (1 female, TARI); 1–19.ii.1964, K. S. Lin (1 female, TARI); vi.1967, K. S. Lin (1 female, TARI).

***Cosmocomoidea kodaiana* Mani and Saraswat, 1973**

Material examined. Taiwan, Chiayi Co., Alishan, 2,450 m, 16.vi.1965, K. S. Lin (1 female, TARI). Taipei City: Hsintien, 31.iii.1963, K. S. Lin (3 females, TARI); 5–6.iv.1963, K. S. Lin (2 females, TARI); 15–19.iv.1963, K. S. Lin (1 female, TARI); Hsintien, 6.iv.1964, K. S. Lin (1 female, TARI); 11–21.iv.1964, K. S. Lin (2 females, TARI). Tsaoshan (20 km N of Taipei City), 14.viii.1963, K. S. Lin (1 female, TARI). Wulai (20 km S of Taipei City), 1.vi.1962, W. H. Ting (2 females, TARI).

***Cosmocomoidea ?latipennis* (Girault, 1911)**

Gonatocerus (*Cosmocomoidea*) *?latipennis*: Triapitsyn 2013b: 150 (Nantou Co.).

Material examined. Taiwan, Taipei City, 20–30.xii.1963, K. S. Lin (1 female, TARI).

***Cosmocomoidea tenuis* Xu, Lin and Hu, 2016 (Fig. 32)**

Material examined. Taiwan: Taichung, Shengkuang, 1,850 m, 20.ix.1968, K. S. Lin (4 females, 1 male, TARI). Taipei City, Hsintien, 31.iii.1963, K. S. Lin (1 female, TARI).

Description. Male (slide-mounted specimen from Taiwan, Fig. 32). Body length 1.28 mm. Similar to female, as described by Aishan *et al.* (2016), except for the normal sexually dimorphic features such as antenna and genitalia. Antenna with pedicel small, about as long as wide; flagellomeres more or less subequal in length (F1 the shortest and the widest), each with many mps. Fore wing 2.8 times as long as

Fig. 32. *Cosmocomoidea tenuis*, male (Shengkuang, Taichung, Taiwan): habitus (a slide mount).

wide, longest marginal seta 0.25 times maximum wing width; hind wing about 18 times as long as wide, longest marginal seta 2.3 times maximum wing width. Gaster relatively shorter than in female, shorter than mesosoma.

Comments. This species was previously known from the females only, all collected in Fujian, China (Aishan *et al*. 2016).

***Cosmocomoidea* sp.**

Gonatocerus (*Cosmocomoidea*) sp.: Triapitsyn and Shih, 2014: 675–676 (Taichung).

Host in Taiwan: *Kolla paulula* (Walker, 1858) (Cicadellidae) (Triapitsyn & Shih 2014).

***_Erythmelus_ (_Erythmelus_) _nuinu_ Triapitsyn, 2003**

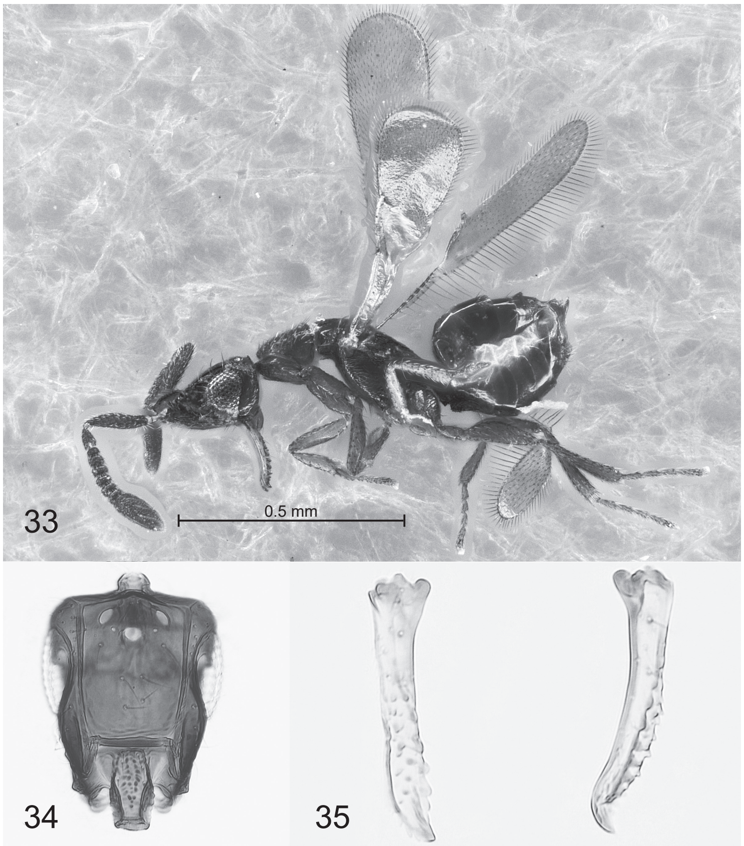
Material examined. Taiwan, Nantou Co., E of Shankan, 2,000–2,200 m, 28.v.1990, J. M. Heraty (1 female, CNC).

***_Erythmelus_ (_Parallelaptera_) _funiculi_ (Annecke and Doutt, 1961)**

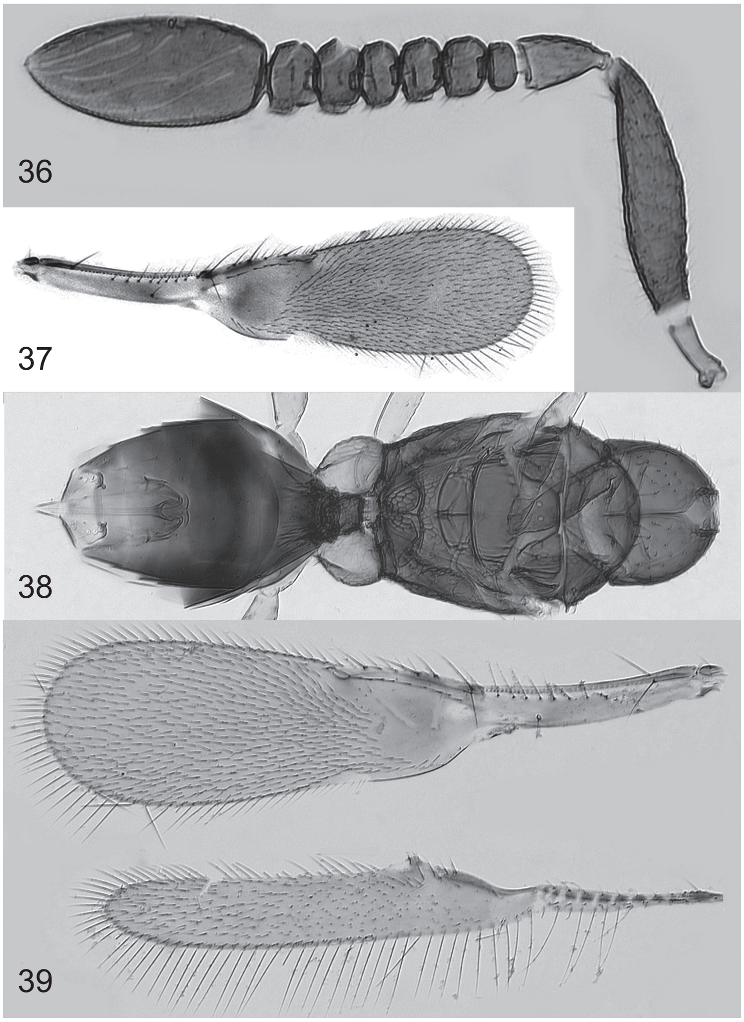
Material examined. Taiwan, Taichung, Hsuchsan (above Shan Liu), Gieu Hut, 3,200 m, 8–10.v.1991, A. Smetana (1 female, CNC).

***_Eubroncus scutatus_ Manickavasagam and Palanivel, 2015 (Figs. 33–43)**

Material examined. Taiwan: Taichung, Hsinkangshan (above Chengkung), 350 m, 25–28.iv.1995, A. Smetana (1 female, 2 males, CNC). Taipei City: 14–22.xi.1990, C. K. Starr, yellow pan trap (1 female, CNC); City Park, 1–19.xii.1990, J. T. Chao, yellow pan trap (1 female, CNC).

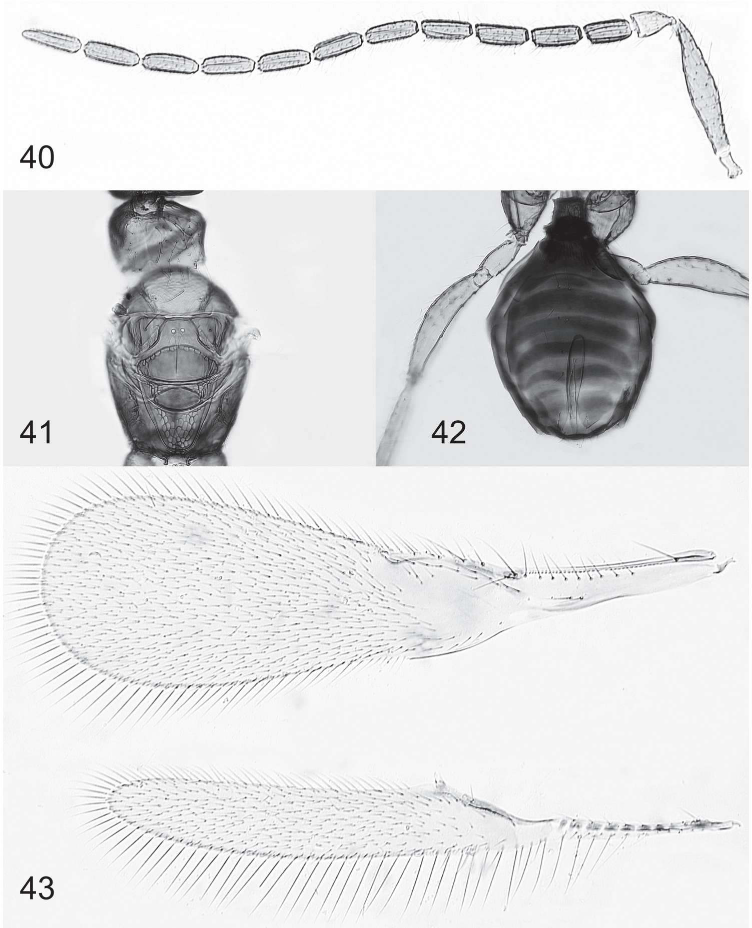


Figs. 33–35. *Eubroncus scutatus*, females (Taipei City, Taiwan): 33. Habitus in lateral view; 34. Head in dorsal view; 35. Mandibles.



Figs. 36–39. *Eubroncus scutatus*, females: 36. Antenna (Taipei City, Taiwan); 37. Fore wing (paratype, Mulakadu, Kallakuruchi Taluk, Tamil Nadu, India; photograph courtesy of S. Manickavasagam); 38. Mesosoma and metasoma (Taipei City, Taiwan); 39. Fore and hind wings (Taipei City, Taiwan).

Redescription (specimens from Taiwan). Female. Body length 0.83–0.89 mm (dry-mounted specimens, as in Fig. 33). Dark brown: head, mesosoma laterally, propodeum dorsally, petiole; brown: rest of body, antenna (except radicle); light brown: mandible (Fig. 35), radicle, and legs. Head (Fig. 34) with vertex smooth. Antenna (Fig. 36) with scape minus radicle with reticulate sculpture, 4.2 times as long as wide; funicular segments short and transverse, F1 without mps, F2–F6 each with 2 mps; clava 2.1–2.2 times as long as wide, with 7 mps, a little longer than combined length of F2–F6. Mesosoma sculptured as in Fig. 38 (midlobe of mesoscutum and propodeum medially with reticulate sculpture). Fore wing (Fig. 39) about 4.0 times as long as wide; disc infuscate throughout, with a row of long setae behind submarginal vein and with characteristic several discolored marginal setae on posterior margin next to a small bare area behind stigmal vein; longest marginal seta 0.34 times maximum width of wing. Hind wing (Fig. 39) 8.4 times as long as wide; disc infuscate and



Figs. 40–43. *Eubroncus scutatus*, male [Hsinkangshan (above Chengkung), Taichung, Taiwan]: 40. Antenna; 41. Mesosoma; 42. Metasoma; 43. Fore and hind wings.

with a few somewhat longer setae behind and just beyond apex of venation; longest marginal seta 1.2 times maximum width of wing. Coxae with reticulate sculpture. Petiole about as long as wide, strongly reticulate. Gaster (Fig. 38) shorter than mesosoma; first gastral tergum and first gastral sternum with numerous sclerotized ridges; ovipositor about as long as mesotibia, exserted slightly beyond gastral apex.

Male. Body length (dry-mounted specimens) 0.825–0.925 mm. Similar to female except for the normal sexually dimorphic features such as antenna and genitalia, and the following. Body mostly dark brown except pronotum and most of gaster brown; scape and pedicel brown, flagellum dark brown; legs light brown. Antenna (Fig. 40) with scape minus radicle reticulate, 5.0 times as long as wide; flagellomeres more or less subequal in length (the apical ones slightly longer), longer than wide, each with several mps. Mesosoma sculptured as in Fig. 41. Fore wing (Fig. 43) 3.5 times as long as wide and its disc without a well-defined small bare area behind stigmal vein next to several discolored marginal setae on posterior margin; longest marginal seta 0.36 times maximum wing width. Hind wing (Fig. 43) 8.7 times as long as wide and its disc without a few somewhat longer setae behind and just beyond apex of venation; longest marginal

seta about as long as maximum width of wing. Genitalia (Fig. 42) length 0.14 mm.

Diagnosis. I assign these interesting specimens to *E. scutatus* Manickavasagam and Palanivel, 2015, previously known only from India (Anwar *et al*. 2015; Palanivel & Manickavasagam 2015). In the female specimens from Taiwan, the discal setae along the posterior margin of the fore wing extend to before the level of the middle of the marginal vein (Fig. 39) whereas those appear to extend only past the level of the middle of the marginal vein in the fore wing illustrated by Palanivel & Manickavasagam (2015, p. 7154, Fig. 7). That, however, was due to some of the discal setae being rubbed off as these are present in the paratype female of *E. scutatus* (Fig. 37) and also in other conspecific specimens from India (S. Manickavasagam, personal communication). It differs from *E. prodigiosus* (Yoshimoto, Kozlov and Trjapitzin, 1972) in having a longer scape (minus radicle) of the female antenna, which is 4.2 times as long as wide (about 3.0 times as long as wide in *E. prodigiosus*, Fig. 68), and also in having the midlobe of the mesoscutum with a reticulate sculpture (almost entirely smooth in *E. prodigiosus*, Fig. 69) and the pronotum faintly divided mediolongitudinally (entire in *E. prodigiosus*). The feature of pronotum being or being not divided mediolongitudinally, however, may not be the best practical character for separation of the species of *Eubroncus* Yoshimoto, Kozlov and Trjapitzin, 1972 because it is often difficult to figure out correctly. For instance, it is used in the keys by Jin & Li (2014) and Palanivel & Manickavasagam (2015) to separate *E. indicus* Hayat and Khan, 2009 from West Bengal, India, which has been known from the single holotype whose body is dry-mounted on a card and described without providing the important diagnostic details of sculpture, particularly on vertex and mesosoma (Hayat & Khan 2009).

Recently, the diagnosis of *E. indicus* was updated by Anwar *et al*. (2015) based on the holotype female. I have examined the following specimens of *E. indicus*: Nepal, Dhawalagiri (Dhaulagiri) Zone, Goropani Pass, East ridge (also spelled as Ghoropani, Gorepani, or Ghorepani), ca. 3,000 m, 7.x.1983, A. Smetana, mountain meadow, screen sweeping (2 females, 2 males, CNC). It is a new record for the country. In the females, whose body length is about 1.05 mm, the vertex is almost smooth (with a faint, inconspicuous, cell-like sculpture better seen in slide-mounted specimens), the pronotum is with a trace of an inconspicuous, short median carina at the anterior margin only which possibly could be interpreted, in slide-mounted specimens, as a "faint longitudinal carina medially" in Jin & Li's (2014) key, the mesoscutum, scutellum and propodeum medially are mostly almost smooth and with 8 large foveae at the frenal line medially (Fig. 44), the fore wing (Fig. 46) is 3.75 times as long as wide and its disc has a row of long setae behind submarginal vein, and the hind wing (Fig. 46) is very wide (7.5 times as long as wide) and its disc with a group of very long setae behind and just beyond the apex of venation. Thus, these specimens also fit very well the description and illustrations of *E. hani* Jin and Li, 2014 from the similar altitude in Yunnan, China (Jin & Li 2014); therefore, *E. hani* syn. nov. is hereby synonymized under *E. indicus*.

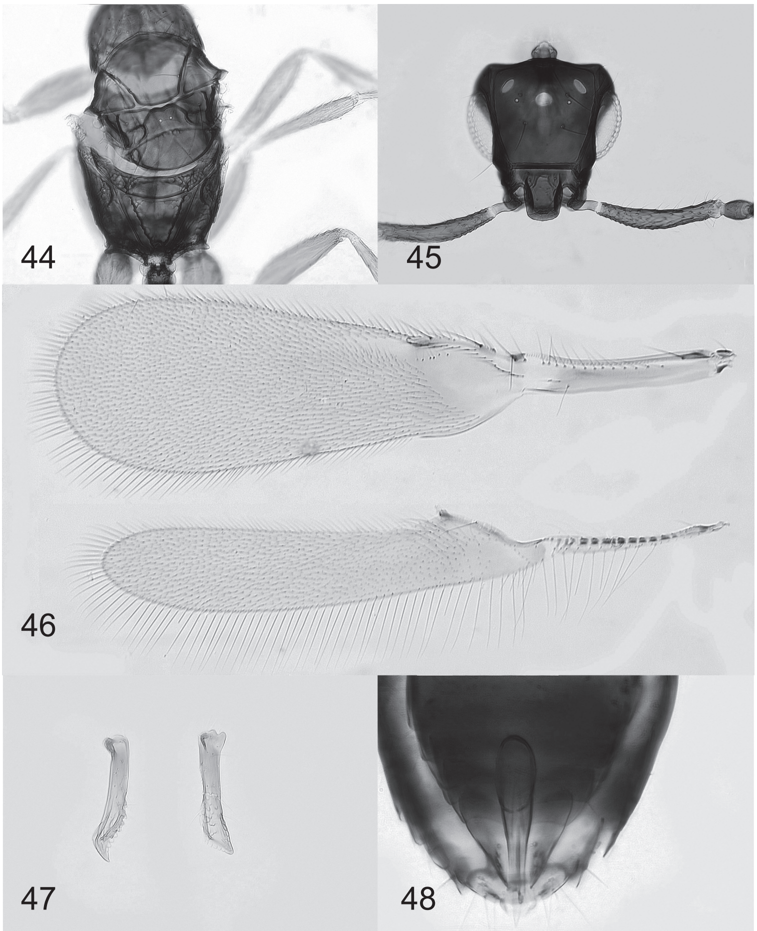
Eubroncus scutatus differs from *E. tibetanus* Jin and Li, 2014 from Tibet, China, to which it keys in Jin & Li (2014), and also from *E. vertexus* Jin and Li, 2014 from Yunnan in having an entirely smooth vertex, from *Eubroncus orientalis* Yoshimoto, Kozlov and Trjapitzin, 1972 (to which it is very similar and quite likely conspecific) only in having a relatively longer ovipositor (about 1.0 times length of mesotibia versus about 0.7 times in *E. orientalis*, but we do not know the range of variation of this character in both nominal taxa), and from *E. indicus* in having a reticulate propodeum medially and presence of strong ridges on the first gastral tergum [these are absent in the latter species according to

Hayat & Khan (2009) and Anwar *et al*. (2015)], so its first gastral tergum is nearly smooth. The males of *E. scutatus* and *E. orientalis* are practically indistinguishable; the latter species probably has a wide distribution range in the Oriental region.

Hosts. Unknown.

Comments. I have examined the following extralimital specimen of *E. prodigiosus*: Russia, Primorskiy kray, Ussuriyskiy rayon, Gornotayozhnoye, 12.vii.2000, M. V. Michailovskaya (1 male, UCRC).

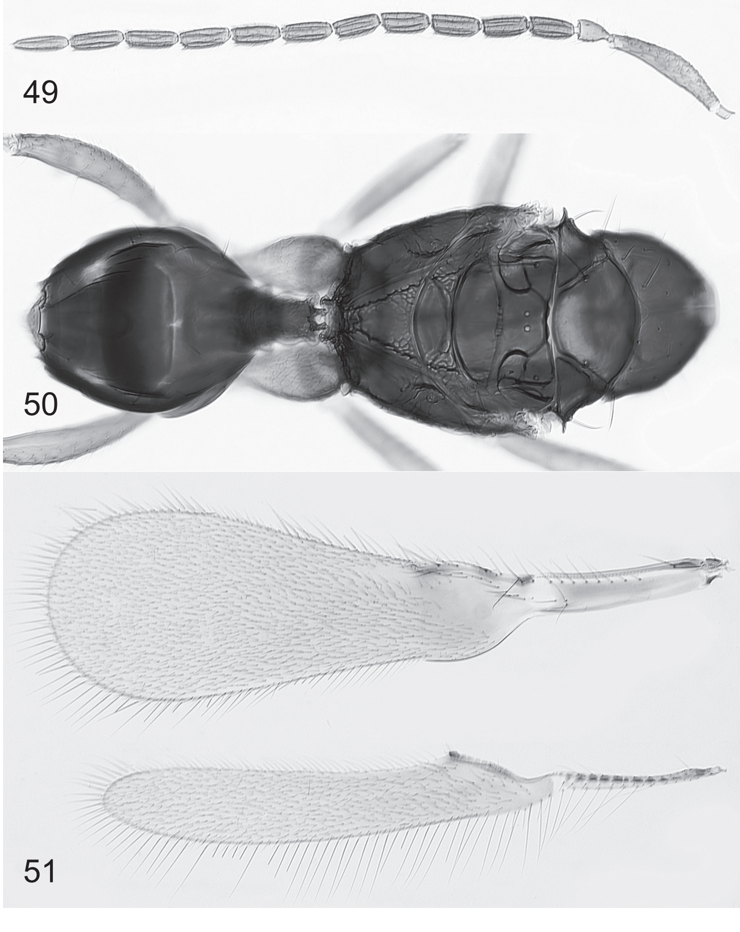
The previously unknown male of *E. indicus* is described, as follows (specimens from Nepal). Length of head (only one specimen measured) 0.267 mm, length of mesosoma plus metasoma 0.916–0.972 mm (slide-mounted specimens). Similar to female, as described by Hayat & Khan (2009) and re-diagnosed and illustrated by Anwar *et al*. (2015), except for the normal sexually dimorphic features such as antenna and genitalia, and the following. Body dark brown to black; scape and pedicel brown, flagellum dark brown; legs brown except metacoxa light brown. Vertex (Fig. 45) almost smooth (with a very faint, inconspicuous cell-like sculpture better visible under high magnification in slide-mounted specimens); mandibles as in Fig. 47. Antenna (Fig. 49) with scape reticulate, 5.2–6.0 times as long as wide;



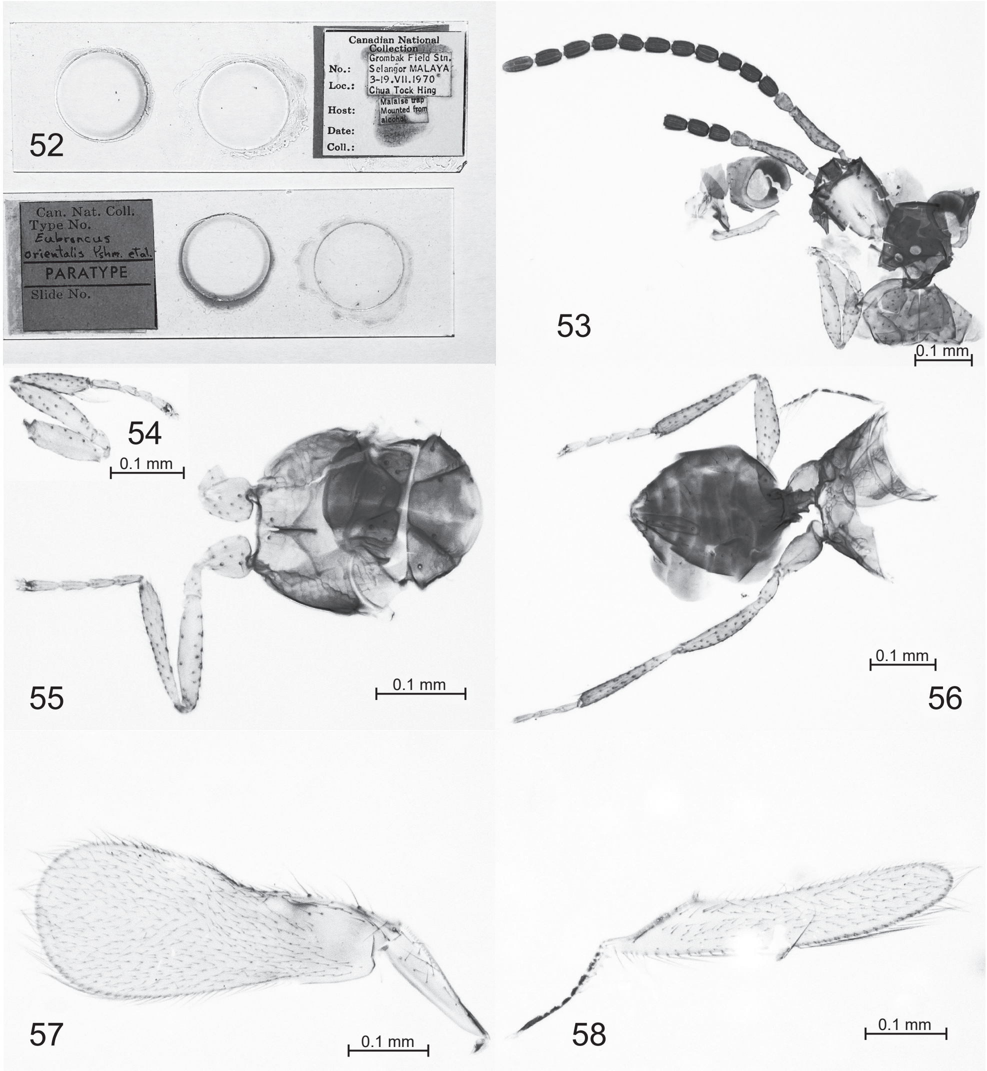
Figs. 44–48. *Eubroncus indicus* (Goropani Pass, Dhawalagiri Zone, Nepal): 44. Female mesosoma; 45. Male head and scape; 46. Female fore and hind wings; 47. Male mandibles; 48. Male genitalia.

flagellomeres more or less subequal in length (the apical ones slightly longer), longer than wide, each with several mps. Mesosoma sculptured as in Fig. 50. Fore wing (Fig. 51) 3.5–3.6 times as long as wide and its disc with a row of long setae behind submarginal vein; longest marginal seta about 0.34 times maximum wing width. Hind wing (Fig. 51) 8.0–8.1 times as long as wide; longest marginal seta about as long as maximum width of wing; disc with much shorter setae behind and just beyond the apex of venation than in female (Fig. 46). First gastral sternum with prominent ridges; genitalia (Fig. 48) length 0.149–0.157 mm.

Using this opportunity, the male of *E. orientalis* is redescribed and illustrated in detail to complement the original description, and its previously unknown female is described. This is necessary to include the type species of the genus in the key below; it was omitted from the world keys to females of *Eubroncus* of Jin & Li (2014) and Palanivel & Manickavasagam (2015). I have examined its holotype male (on point) and a male paratype (dissected on a slide, Figs. 52–58), both in CNC, the holotype labeled: 1. "Grombak Field Stn. Selangor MALAYA 3-19.VII.1970 Chua Tock Hing"; 2. "Malaise trap Mounted from alcohol"; 3. "HOLOTYPE *Eubroncus orientalis* Yshm *et al*."; 4. "HOLOTYPE CNC No. 19026." The paratype has the same data (Fig. 52). The correct type locality of *E. orientalis* is University



Figs. 49–51. *Eubroncus indicus*, male (Goropani Pass, Dhawalagiri Zone, Nepal): 49. Antenna; 50. Mesosoma and metasoma; 51. Fore and hind wings.



Figs. 52–58. *Eubroncus orientalis*, male (paratype, University of Malaya Field Station, 16 km E of Gombak, 03°19’30”N, 101°45’12”E, Selangor, Malaysia; photographs courtesy of S. van Noort): 52. Slide; 53. Head and antennae; 54. Fore leg; 55. Mesosoma minus propodeum; 56. Propodeum and metasoma; 57. Fore wing; 58. Hind wing.

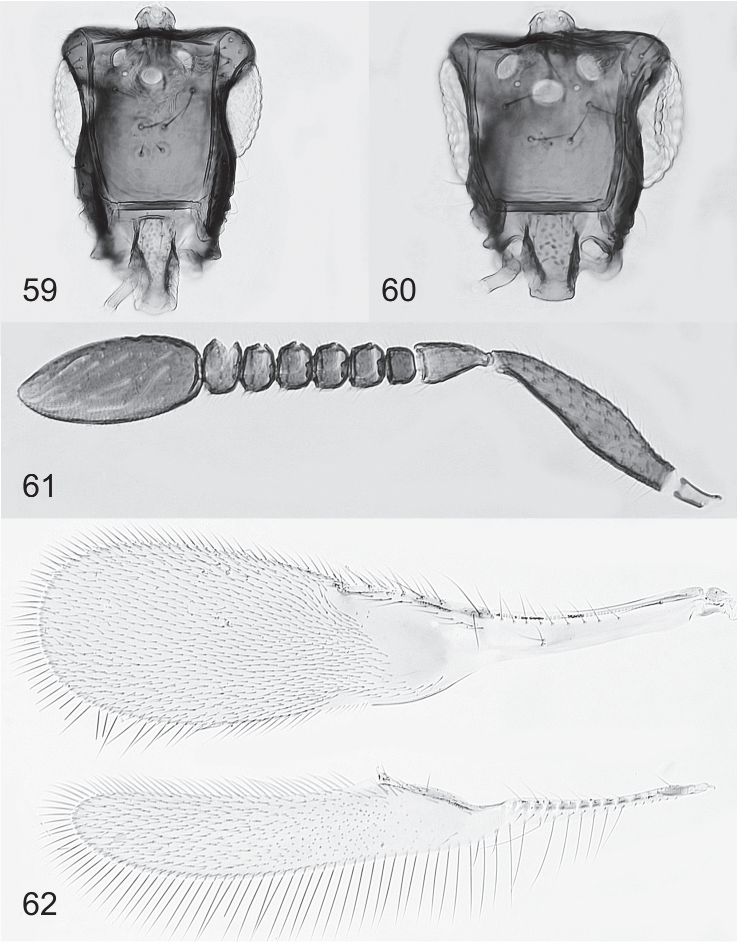
of Malaya Field Station, 16 km E of Gombak, 03°19’30”N, 101°45’12”E, 262 m, Selangor, Malaysia (Triapitsyn & Berezovskiy 2002), who also provided brief descriptive notes on its type specimens and a key to the males of the two species of *Eubroncus* known then. Contrary to the original description of Yoshimoto *et al*. (1972), it has the fore wing normal for the genus (better seen in the dry-mounted holotype), with a group of 3 or 4 setae at apex of venation separating a small bare area just beyond venation at apex of the stigmal vein. The fore wing of the paratype male (Fig. 57), which was also illustrated, as a drawing, by Yoshimoto *et al*. (1972), is just poorly mounted on the slide. The holotype and paratypes of *E. orientalis* had been compared with the following dry-mounted male in CNC which was then slide-mounted: Indonesia, Sulawesi Island, North Sulawesi, Bogani Nani Wartabone

National Park (as "Dumoga-Bone Nat. Park"), Toraut, v.1985, J. S. Noyes. A matching female on a slide in CNC (Indonesia, Sulawesi Island, North Sulawesi, Kotamobagu, Gunung Muajat, 1,760 m, v.1985, J. S. Noyes), also from North Sulawesi, is used to describe the previously unknown female sex of this species below. Of course, it would be preferable to have a matching female from or near the type locality of *E. orientalis* in Malaysia, but unfortunately no such specimen is currently available besides that from Thailand, Phetchaburi, Kaeng Krachan National Park, 12°47'53"N 99°27'11"E, 290 m, 24–26.vi.2008, B. V. Brown (1 female, UCRC), which comes from the same Malay Peninsula (and what it is also important from about the same altitude) as the holotype of this species, and is undoubtedly conspecific with the female from Sulawesi Island. Its ovipositor is 0.7 times as long as mesotibia. Very similar, if not conspecific, specimens are also known to me: Papua New Guinea, Morobe Province, Tekadu: xi.1999–iv.2000, "binatung brigade" (1 male, UCDC); 7°38'S 146°34'E, i.2000, T. S. Sears and "binatung brigade" (1 male, UCRC).

Description (female of *E. orientalis* from Sulawesi Island). Body and antenna (except radicle) brown; mandible, radicle and legs pale light brown. Vertex (Fig. 59) almost smooth (with a very faint, inconspicuous cell-like sculpture visible only under high magnification in slide-mounted specimen). Antenna (Fig. 61) with scape minus radicle with reticulate sculpture, 4.75 times as long as wide; funicular segments short and transverse, F1 the shortest and the narrowest funicular segment and without mps, F2–F6 subequal in length (F6 the widest funicular segment) and each with 2 mps; clava 2.4 times as long as wide, with 7 mps, a little longer than combined length of F2–F6. Mesosoma sculptured as in Fig. 63 (midlobe of mesoscutum and propodeum medially with reticulate sculpture); frenal line on scutellum with a complete row of foveae. Fore wing (Fig. 62) 3.8 times as long as wide; disc strongly infuscate throughout, with a row of long setae behind submarginal vein and with characteristic several discolored marginal setae on posterior margin next to a small bare area behind stigmal vein; longest marginal seta about 0.28 times maximum width of wing. Hind wing (Fig. 62) 7.7 times as long as wide; disc strongly infuscate and with a few somewhat longer setae behind and just beyond apex of venation; longest marginal seta almost equal to maximum width of wing. Coxae with reticulate sculpture. Petiole (Fig. 63) almost as wide as long, reticulate. Gaster (Fig. 63) shorter than mesosoma; first gastral tergum with a few and first gastral sternum with numerous sclerotized ridges; ovipositor 0.74 times as long as mesotibia, exserted slightly beyond gastral apex.

Measurements (mm). Body (of the dry-mounted specimen prior to slide-mounting) 1.025; head: 0.283; mesosoma 0.449; mesoscutum: 0.112; scutellum: 0.121; petiole 0.057; gaster 0.35; ovipositor 0.141. Antenna: scape (excluding radicle) 0.173; pedicel 0.058; F1 0.021; F2 0.027; F3 0.026; F4 0.027; F5 0.026; F6 0.07; clava 0.27. Fore wing 0.904 : 0.24; longest marginal seta 0.067. Hind wing 0.861 : 0.112; longest marginal seta 0.109. Mesotibia: 0.19.

Redescription (male of *E. orientalis* from Sulawesi Island). Body length (of the dry-mounted specimen prior to slide-mounting) 0.76 mm; head length 0.215 mm; length of mesosoma plus metasoma 0.69 mm. Similar to female except for the normal sexually dimorphic features such as antenna and genitalia, and the following. Scape and pedicel pale light brown. Head as in Fig. 60. Antenna (Fig. 64) with scape minus radicle reticulate; flagellomeres subequal in length (apical ones slightly longer), longer than wide, each with several mps. Mesosoma sculptured as in Fig. 65. Fore wing (Fig. 67) 3.3 times as long as wide, without a well-defined small bare area behind stigmal vein next to several discolored marginal setae on posterior margin; longest marginal seta 0.32 times maximum wing width. Hind wing (Fig. 67) 8.4 times as long as wide; disc infuscate

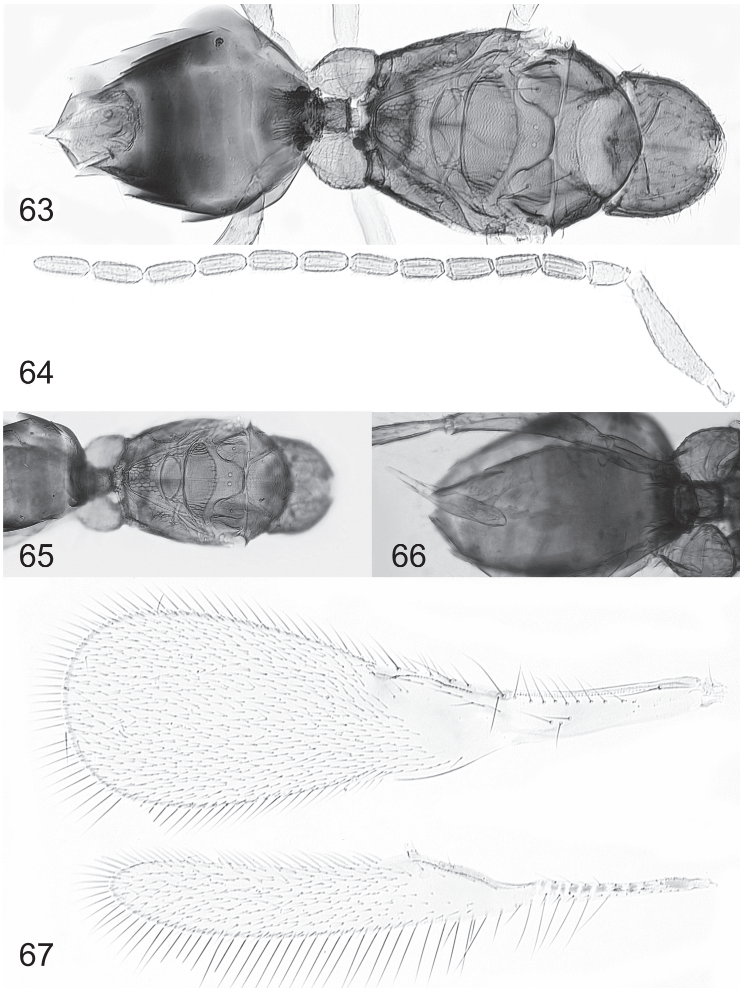


Figs. 59–62. *Eubroncus orientalis* (female—Gunung Muajat, Kotamobagu, North Sulawesi, Sulawesi Island, Indonesia; male—Toraut, Bogani Nani Wartabone National Park, North Sulawesi, Sulawesi Island, Indonesia): 59. Female head in dorsal view; 60. Male head in dorsal view; 61. Female antenna; 62. Female fore and hind wings.

and without a few somewhat longer setae behind and just beyond apex of venation; longest marginal seta 0.9 times maximum width of wing. Genitalia (Fig. 66) length 0.142 mm.

Key to the described species of *Eubroncus* in the world, both sexes

1 Female: flagellum clavate, consisting of 6-segmented funicle and an entire clava (as in Figs. 36, 61, 68) ························ 2
– Male: flagellum filiform, 11-segmented (as in Figs. 40, 49, 53, 64, 75) ············ 7
2(1) Vertex at least partially with strong reticulate (scale-like) sculpture ············ 3
– Vertex smooth or at most with faint, inconspicuous cell-like sculpture better visible under high magnification in slide-mounted specimens ····················4
3(2) Vertex entirely with strong reticulate (scale-like) sculpture; hind wing disc without a group of long setae behind and just beyond apex of venation ··························· *E. vertexus* Jin and Li, 2014
– Vertex only partially with strong reticulate (scale-like) sculpture (more or less smooth around ocelli); hind wing disc with a group of long setae behind and just beyond apex of venation ································ *E. tibetanus* Jin and Li, 2014



Figs. 63–67. *Eubroncus orientalis* (female—Gunung Muajat, Kotamobagu, North Sulawesi, Sulawesi Island, Indonesia; male—Toraut, Bogani Nani Wartabone National Park, North Sulawesi, Sulawesi Island, Indonesia): 63. Female mesosoma and metasoma; 64. Male antenna; 65. Male mesosoma and petiole; 66. Male metasoma; 67. Male fore and hind wings.

4(2) Clava distinctly longer than funicle; midlobe of mesoscutum almost smooth, at most with a faint, inconspicuous cell-like sculpture ······························ 5

– Clava at least a little shorter than funicle; midlobe of mesoscutum with a distinct reticulate sculpture ················ 6

5(4) Fore wing with a row of long setae behind submarginal vein (Fig. 46); hind wing disc with a group of very long setae behind and just beyond apex of venation (Fig. 46) ····························· ··········*E. indicus* Hayat and Khan, 2009

– Fore wing without a row of long setae behind submarginal vein (as in Fig. 70); hind wing disc without a group of long setae behind and just beyond apex of venation ······································· ······ *E. prodigiosus* (Yoshimoto, Kozlov and Trjapitzin, 1972)

6(4) Ovipositor about 0.7 times as long as mesotibia ······································· ······*E. orientalis* Yoshimoto, Kozlov and Trjapitzin, 1972

– Ovipositor about as long as mesotibia ······*E. scutatus* Manickavasagam and Palanivel, 2015

7(1) Vertex at least partially with strong reticulate (scale-like) sculpture ············ 8

– Vertex smooth or at most with faint, inconspicuous cell-like sculpture better visible under high magnification in slide-mounted specimens ···················9

8(7) Vertex entirely with strong reticulate (scale-like) sculpture ················· *E. vertexus* Jin and Li, 2014

– Vertex only partially with strong reticulate (scale-like) sculpture (more or less smooth around ocelli) (Fig. 73) ····························*E. tibetanus* Jin and Li, 2014

9(7) Midlobe of mesoscutum almost smooth, at most with a faint, inconspicuous cell-like sculpture ·································· 10

– Midlobe of mesoscutum with a distinct reticulate sculpture (Figs. 41 and 65) ········ *E. orientalis* Yoshimoto, Kozlov and Trjapitzin, 1972 and *E. scutatus* Manickavasagam and Palanivel, 2015

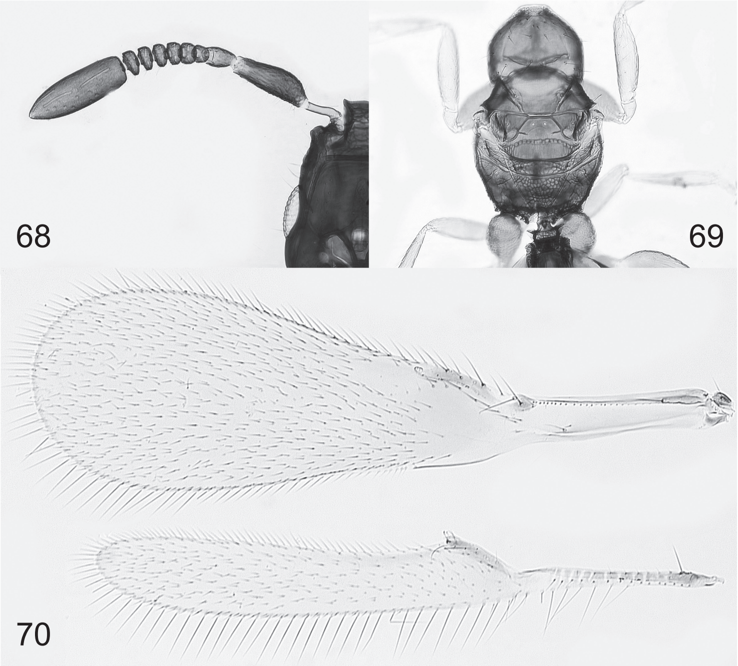
10(9) Propodeum mostly smooth medially (Fig. 50); fore wing with a row of long setae behind submarginal vein (Fig. 51) ··········*E. indicus* Hayat and Khan, 2009

– Propodeum reticulate medially (Fig. 69); fore wing without a row of long setae behind submarginal vein (Fig. 70) ··········*E. prodigiosus* (Yoshimoto, Kozlov and Trjapitzin, 1972)

***Eubroncus ?tibetanus Jin and Li, 2014 (Figs. 71–76)**

Material examined. Taiwan, Taichung, Hsinkangshan (above Chengkung), 350 m, 25–28.iv.1995, A. Smetana (1 male, CNC).

Extralimital material examined. Japan: Honshu Island: Gifu Prefecture, 8 km SE of Osaka, 750 m, 1.viii.1980, A. and Z. Smetana (2 males, CNC). Ibaraki Prefecture, Tsukuba, Matsushiro, 26.vi–4.vii.1989, M. J. Sharkey (2 females, 1 male, CNC). Kyushu Island: Fu-

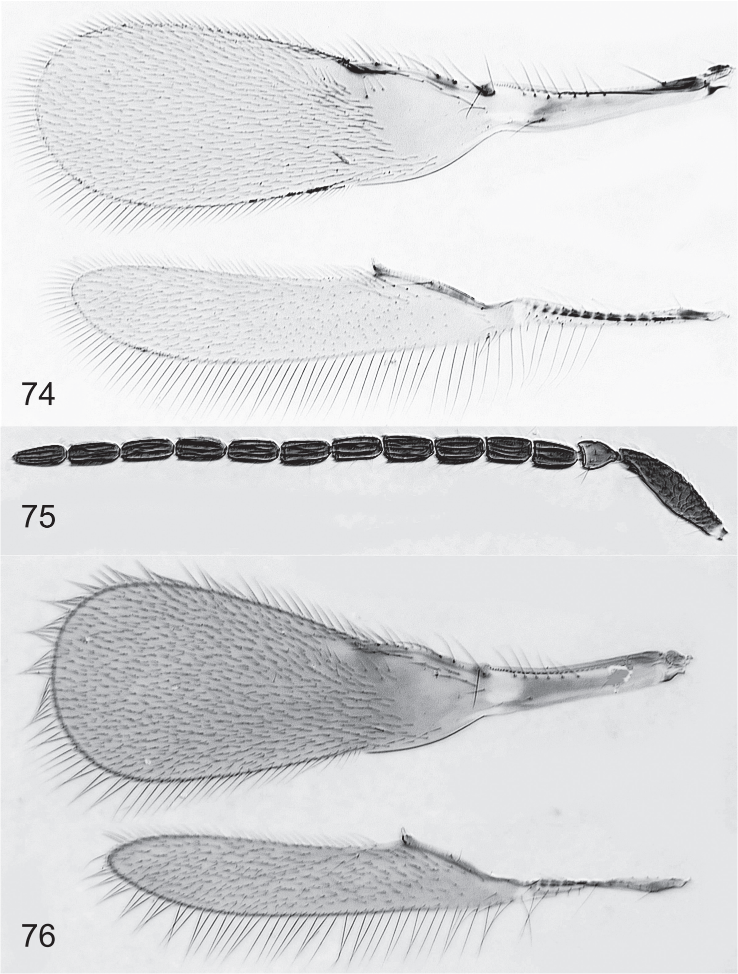


Figs. 68–70. *Eubroncus prodigiosus* (Gornotayozhnoye, Ussuriyskiy rayon, Primorskiy kray, Russia): 68. Female antenna; 69. Male mesosoma and petiole; 70. Male fore and hind wings.

Figs. 71–73. *Eubroncus tibetanus*, male (Mt. Tachibana, Fukuoka Prefecture, Kyushu Island, Japan): 71. Mandibles; 72. Genitalia; 73. Body.

kuoka Prefecture: Mt. Hiko: 4–11.viii.1989, M. J. Sharkey, K. Takeno (1 male, CNC); 11–18. viii.1989, K. Takeno, M. J. Sharkey (1 female, 1 male, CNC). Mt. Tachibana: 6–12.v.1979, K. Yamagishi (5 females, 1 male, CNC); 13–19. v.1979, K. Yamagishi (1 male, CNC); 10–16. vi.1979, K. Yamagishi (1 female, 1 male, CNC); 7–13.vii.1979, K. Yamagishi (1 female, CNC); 15–21.vii.1979, K. Yamagishi (1 female, CNC); 12.viii.1980, C. M. Yoshimoto (4 females, 4 males, CNC). Miyazaki Prefecture, Aya, Teruha Bridge, 32°01'N 131°11'E, 200 m, 20–22.ix.1996, L. Masner (1 female, CNC). Thailand, Chiang Mai, Doi Inthanon National Park, near park headquarters, 18.54°N 98.52°E, 1,300 m, 30.vi.2006, Y. Areeluck (1 male, UCRC). Two females from Mt. Tachibana, Japan were misidentified by C. M. Yoshimoto as *E. prodigiosus*. These are new country records of *E. tibetanus*; also a very similar, but probably an undescribed species of *Eubroncus* is known to me from the mountains of Luzon Island, the Phillipines [3 females in the California Academy of Sciences, San Francisco, California, USA (CAS)].

Comments. A brief description of the previously unknown male of *E. tibetanus* is as follows (specimens from Japan). Body length 0.76–1.15 mm (dry-mounted specimens). Similar to female, as described by Jin & Li (2014), except for the normal sexually dimorphic features such as antenna and genitalia, and the following. Body dark brown; scape and pedicel brown, flagellum dark brown; mandible and legs light brown to brown except metacoxa dark brown. Vertex (Fig. 73) mostly reticulate except almost smooth around ocelli; mandibles as in Fig. 71. Antenna (Fig. 75) with scape reticulate, 3.7 times as long as wide; flagellomeres more or less subequal in length (the apical ones slightly longer), longer than wide, each with several mps. Mesosoma sculptured as in Fig. 73. Fore wing (Fig. 76) 3.2 times as long as wide and its disc with a row of long setae behind submarginal vein; longest marginal seta about 0.33 times maximum wing width. Hind wing (Fig. 76) 7.6 times as long as wide; longest marginal seta about 0.8 times maximum width of wing; disc with much shorter setae behind and just beyond the apex of ve-



Figs. 74–76. *Eubroncus tibetanus* (Mt. Tachibana, Fukuoka Prefecture, Kyushu Island, Japan): 74. Female fore and hind wings; 75. Male antenna; 76. Male fore and hind wings.

nation than in female (Fig. 74). Genitalia (Fig. 72) length 0.136 mm.

***Eubroncus* sp.**

Material examined. Taiwan, New Taipei City, Wulai District, Fushan, 400–600 m, 28.xi.1997, B. J. Sinclair (1 male, CNC).

Comments. This interesting card-mounted specimen seems to represent an undescribed species as it has a unique combination of a strongly reticulate vertex and the propodeum being mostly smooth medially.

***Gonatocerus aegyptiacus* Soyka, 1950**

Material examined. Taiwan: Chiayi Co., Chiayi, 18.vi.1972, K. S. Lin (1 female, TARI). Pingtung Co., Pingtung, 13.iv.1976, C. C. Wu, from eggs of *Nephotettix* sp. on rice (5 females, 1 male, TARI). Taipei City: viii.1963, K. S. Lin (1 female, TARI); 4.xi.1974, K. S. Lin (5 females, TARI).

Host in Taiwan. *Nephotettix* sp. (Cicadellidae).

Extralimital material examined. Japan, Honshu Island, Shimane Prefecture, "Yatsuka-gun, Shimane-cho," 16.ix.1985, K. Miura, from eggs of *N. cincticeps* in rice field (4 females, 1 male, CNC).

***Gonatocerus fuscicornis Walker, 1846**

Material examined. Taiwan, Taipei City, 4.xi.1974, K. S. Lin (1 female, TARI).

***Gonatocerus longicornis Nees ab Esenbeck, 1834**

Material examined. Taiwan: Lu Kang, Chang Hwo, 12.viii.1952, K. S. Lin (2 females, TARI). Pingtung Co., Pingtung, 26.vi.1970, K. S. Lin, sweeping in rice field (10 females, 2 males, TARI). Taipei City: 2.viii.1950, K. S. Lin (1 female, TARI); 6–15.xii.1957, K. S. Lin (1 female, TARI); Hsintien, 31.iii.1963, K. S. Lin (1 female, TARI); 26–31.vii.1963, K. S. Lin (1 female, TARI); viii.1963, K. S. Lin (5 females, TARI); 2–7.ix.1963, K. S. Lin (3 females, TARI); 15–30.ix.1963, K. S. Lin (5 females, TARI); 1–15.x.1963, K. S. Lin (5 females, TARI); 16–31.x.1963, K. S. Lin (1 female, TARI); 4–19.xi.1963, K. S. Lin (5 females, TARI); 20–30.xi.1963, K. S. Lin (1 female, TARI); 20–30.xii.1963, K. S. Lin (1 female, TARI); 1–19.ii.1964, K. S. Lin (1 female, TARI); 3–10.xii.1964, K. S. Lin (1 female, TARI); iii.1965, K. S. Lin (1 female, TARI); vii.1967, K. S. Lin (1 female, TARI); vi.1969, K. S. Lin (1 female, TARI); vii.1969, K. S. Lin (1 female, TARI); 1969, K. S. Lin (1 female, TARI); x.1972, K. S. Lin (1 female, TARI); ix.1974, K. S. Lin (1 female, TARI); 8.x.1974, K. S. Lin (2 females, TARI); 18.xi.1974, K. S. Lin (1 female, TARI). Wulai (20 km S of Taipei City), 20.iii.1963, K. S. Lin (1 female, TARI).

Extralimital material examined. France, Côte-d'Or, Esbarres, 13.vii.1964, J. Barbier (1 female, MNHN). Japan, Honshu Island, Yamaguchi Prefecture, Yamaguchi City: 22.vii.1969, K. S. Lin, in rice field (1 female, TARI); Yoshida, K. Miura, from egg of *Cicadella viridis* (Linnaeus, 1758) on *Lolium multiflorum*: 28.viii.1984 (1 female, CNC); 4.ix.1984 (8 females, 5 males, CNC).

***Gonatocerus* sp(p).**

Lymaenon sp.: Lin 1974: 93–96 [Pingtung, Taipei; key, illustration of a fore wing (consistent with that of *G. aegyptiacus*)], 98–99 (descriptive notes and history of previous records and misidentifications in Taiwan).

Gonatocerus sp.: Chu and Hirashima, 1981: 35–36; Miura *et al*., 1981: 49–50 ("Linnei, Kuantyling, Lungtien, Hsinshih, Kueijen, Chiasien, Matou").

Hosts in Taiwan. *N. lugens* (Stål, 1854) (Delphacidae) (Lin 1974; Chu & Hirashima 1981), as well as *N. cincticeps* (Uhler, 1896) (Lin 1974; Chu & Hirashima 1981) and *Nephotettix* spp. (Miura *et al*. 1981) (Cicadellidae).

Comments. *Lymaenon* sp. of Lin (1974) and *Gonatocerus* sp. of Miura *et al*. (1981) very well could be a mixture of two very similar species of the genus *Gonatocerus* Nees ab Esenbeck, 1834, *G. cincticipitis* Sahad, 1982 and *G. aegyptiacus* Soyka, 1950, both of which are known as sympatric egg parasitoids of the rice leafhoppers and planthoppers in Japan and Republic of Korea (Triapitsyn 2013b). Indeed, as shown above, some of Dr. Kwei-Shui Lin's specimens from Taiwan belong to *G. aegyptiacus*. Differences between them are quite minor (presence or absence of a mps on F5 of the female antenna, often inconsistent between the antennae in the same specimen, and also chaetotaxy on the base of the fore wing (Sahad & Hirashima 1984), which are likely unreliable characters), so *G. cincticipitis* could very well be a synonym of *G. aegyptiacus*. I am reluctant, however, to propose such a synonymy here until a thorough combined morphometric and molecular study is conducted with a statistically sufficient number of fresh specimens of these two nominal species.

The following extralimital specimen of *G. cincticipitis* has been examined: Japan, Honshu Island, Yamaguchi Prefecture, Yamaguchi, 22.vii.1969, K. S. Lin, rice field (1 female, TARI).

***Himopolynema berezovskiyi* Triapitsyn, 2015**

H. Berezovskiyi Triapitsyn, 2015a: 82–84 (Taichung).

***Himopolynema heratyi* Triapitsyn, 2015**
H. heratyi Triapitsyn 2015a: 84–86 (Nantou Co.).

***Himopolynema hishimonus* Taguchi, 1977**
H. hishimonus Taguchi, 1977a: 137–139 (Taipei);.
H. hishimonus Taguchi: Triapitsyn, 2015a: 88–89 (Keelung Co., Pingtung Co., Taichung, Taipei).

Material examined. Taiwan, Taipei City, vii.1967, K. S. Lin (1 female, TARI).

***Himopolynema kslini* Triapitsyn, 2015**
H. kslini Triapitsyn, 2015a: 92–96 (Pingtung Co., Taichung, Taipei).

***Himopolynema parviscutum* Taguchi, 1977**
H. parviscutum Taguchi, 1977a: 140–141 [“Ronshung Spa” (probably the name of a resort hotel which is no longer around), “Chipon Spa” (the latter in Taitung Co.)]; .
H. parviscutum Taguchi: Triapitsyn, 2015a: 96–99 (Pingtung Co., Taipei, Taitung Co.).

***Himopolynema taiwanum* Taguchi, 1977**
H. taiwanum Taguchi 1977a: 142 (Pingtung Co.); .
H. taiwanum Taguchi: Triapitsyn, 2015a: 99–102 (Keelung Co., Taipei).

***Himopolynema tarii* Triapitsyn, 2015**
H. tarii Triapitsyn 2015a: 103–105 (Kaohsiung Co.).

***Himopolynema* sp.**
Himopolynema sp.: Triapitsyn 2015a: 105–109 (Chiayi Co.).

***Litus cynipseus* Haliday, 1833**

Material examined. Taiwan, Nantou Co., Lienhuatse, 750 m, 20.ii–18.iii.1991, C. K. Starr, C. S. Lin (1 female, CNC).

Litus camptopterus Novicky, 1953
L. camptopterus Novicky: Triapitsyn and Berezovskiy, 2004b: 10 (Nantou Co.).

***Lymaenon aureus* (Girault, 1911)**

Material examined. Taiwan: Pingtung Co., Kenting National Park, Hengchun, Kueitzuchiao (as “Kuraru, Heng Chung”), 22–29.v.1965, K. S. Lin (5 females, TARI). Taichung, Wufeng, TARI, 24°01’37.1”N 120°41’45.7”E, 83 m, 4–7.x.2016, S. V. Triapitsyn (2 females, 12 males, UCRC). Taipei City: vii.1967, K. S. Lin (4 females, TARI); viii.1968, K. S. Lin (1 female, TARI).

***Lymaenon bicoloriventris* (Zeya, 1995)**

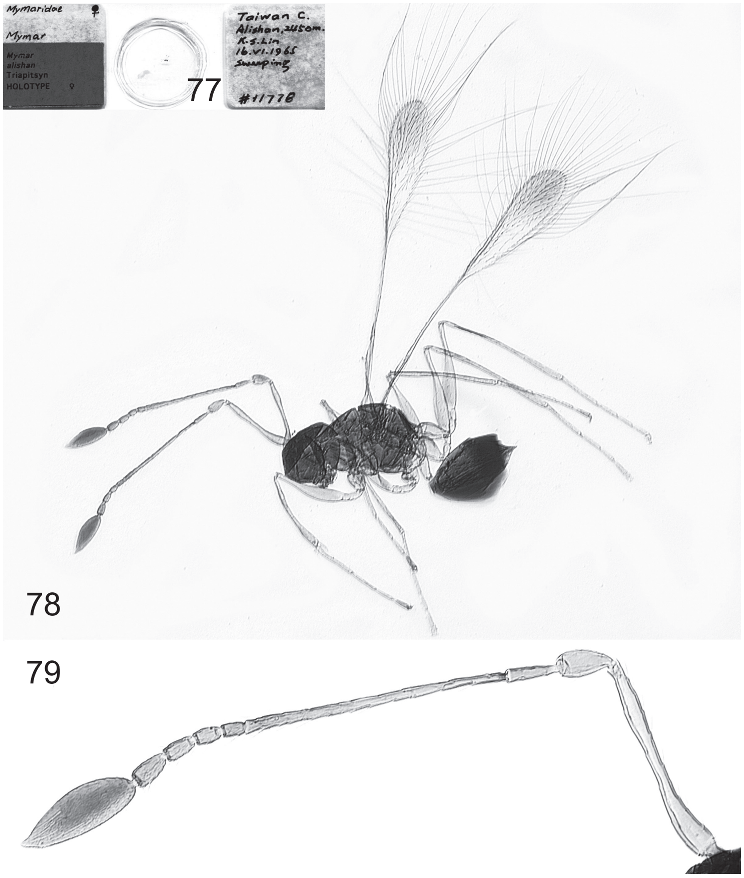
Material examined. Taiwan: Taipei City: vii.1967, K. S. Lin (4 females, TARI); viii.1968, K. S. Lin (1 female, TARI); Hsintien, ix.1968, K. S. Lin (1 female, TARI). Tsaoshan (20 km N of Taipei City), viii.1968, K. S. Lin (1 female, TARI).

***Lymaenon litoralis* (Haliday, 1833)**

Material examined. Taiwan: Chiayi Co., Chiayi, 26.ix.1957, K. S. Lin (1 female, TARI). Taichung, Wufeng, TARI, 24°01’52.4”N 120°41’34.2”E, 76 m, 6–11.x.2016, S. V. Triapitsyn, H.-T. Shih, wild rice field (1 female, TARI). Taipei City: 21–30.vi.1963, K. S. Lin (1 female, TARI); vi.1963, K. S. Lin (1 female, TARI); vii.1967, K. S. Lin (1 female, TARI); viii.1967, K. S. Lin (1 female, TARI); Hsintien, x.1968, K. S. Lin (1 female, TARI); 2.x.1975, K. S. Lin (1 female, TARI). Shong Keng (20 km S of Taipei City), ix.1972, K. S. Lin (1 female, TARI).

***Mymar alishan* Triapitsyn, sp. nov. (Figs. 77–84)**

Type material. Holotype female (TARI) on slide (Fig. 77), labeled: 1. “Taiwan C. Alishan, 2,450 m. K. S. Lin 16.VI.1965 sweeping #11778”; 2. “Mymaridae ♀ *Mymar*”; 3. [magenta] “*Mymar alishan* Triapitsyn HOLOTYPE ♀.” The type locality is in Chiayi Co. The holotype (Fig. 78) is in fair condition, complete, mounted laterally. Paratypes: 1 female and 1



Figs. 77–79. *Mymar alishan*, female (holotype): 77. Slide; 78. Habitus; 79. Antenna.

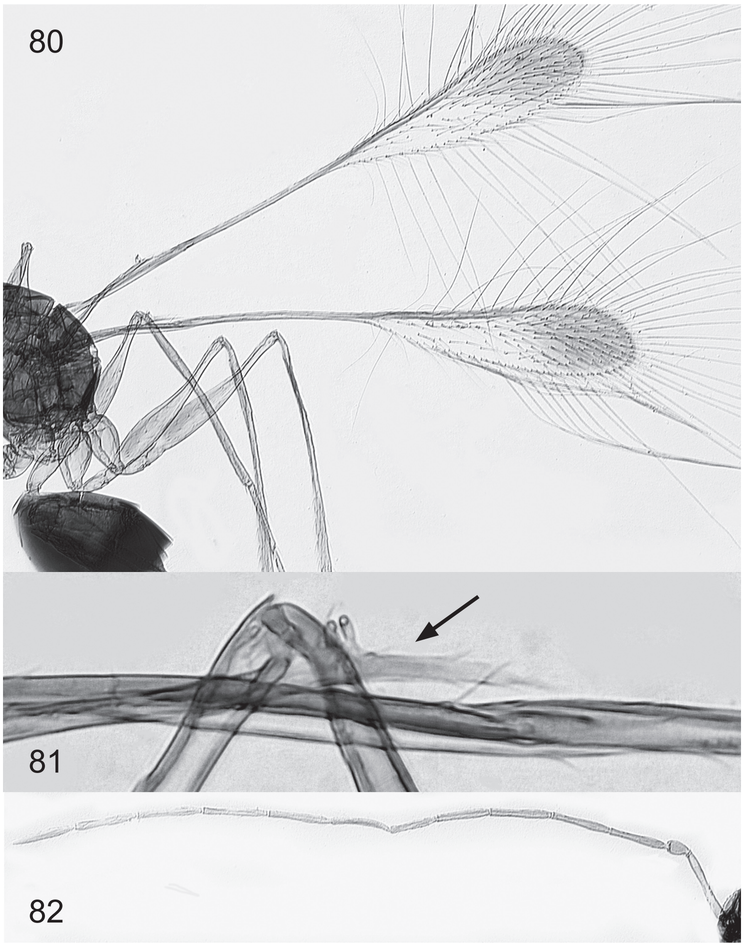
male on slides, same data as the holotype except for K.-S. Lin's slide numbers #11777 and # 11776, respectively.

Description. Female (holotype, Fig. 78). Body mostly dark brown except mesosoma brown and petiole light brown, scape and pedicel brown and flagellum dark brown, legs mostly light brown.

Antenna (Fig. 79) with scape minus short radicle 8.0 times as long as wide, with a constriction in the middle; pedicel longer than F1; F2 the longest funicular segment, slightly longer than combined length of F3–F6 plus clava, and also longer than scape (ratio of length of F2 to clava length 2.05 and ratio of F2 length to combined length of F3–F6 2.1); remaining funicular segments short (F3 the shortest, F6 the longest and the widest); all funicular segments without mps; clava with 7 subapical mps, 2.8 times as long as wide and notched at apex, about as long as combined length of F3–F6.

Wings (Fig. 80). Fore wing disc almost 0.5 times total length of wing, length:width ratio of disc 3.8, disc with about 46 very long marginal setae; venation reaching level of 6th long marginal seta on anterior margin; disc entirely setose (more densely do apically), apical dark area a little less than 0.5 times length of disc. Hind wing 0.23 times length of fore wing, with a narrow, distinct extension (stub) beyond hamuli (Fig. 81) but without a membrane or long setae on stub apex (only with a few very short setae along stub length); ratio of post hamuli stub length to entire hind wing length 0.23.

Metasoma with petiole smooth, about 1.5



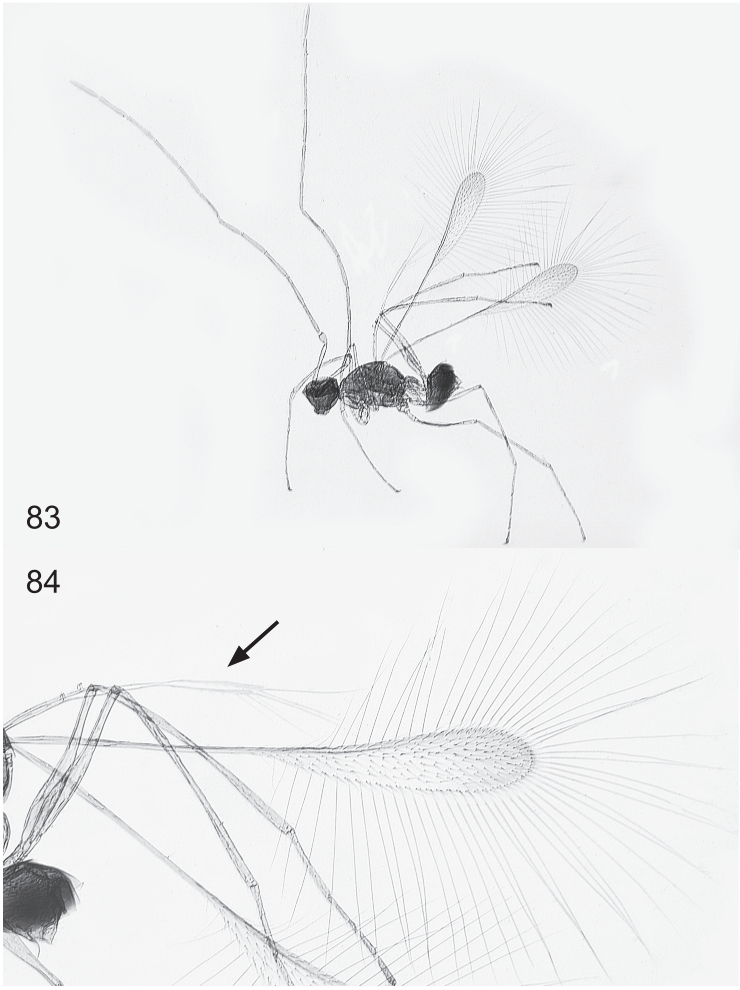
Figs. 80–82. *Mymar alishan*: 80. Female wings (holotype); 81. Female hind wing (holotype; arrow points to post hamuli stub); 82. Male antenna (paratype).

times as long as metacoxa; gaster a little shorter than mesosoma; ovipositor occupies about 0.9 times length of gaster, not exserted beyond gastral apex, 0.65 times length of metatibia.

Measurements (mm) of the holotype. Body (as positioned on the slide) 0.821; mesosoma 0.357; petiole 0.166; gaster 0.338; ovipositor 0.301. Antenna: scape (minus radicle) 0.254; pedicel 0.066; F1 0.052; F2 0.318; F3 0.027; F4 0.03; F5 0.035; F6 0.044; clava 0.155. Fore wing total length 1.088, disc length : width 0.523 : 0.136; longest marginal seta 0.492. Hind wing total length 0.246; post hamuli stub length 0.057.

Variation (paratype). Body length (as positioned on the slide) 0.843 mm. Antenna with scape minus radicle 8.5 times as long as wide; pedicel about as long as F1; F2 a little shorter than combined length of F3–F6 plus clava and also a little longer than scape (ratio of length of F2 to clava length 1.8 and ratio of F2 length to combined length of F3–F6 1.7); clava 3.3 times as long as wide. Fore wing disc 4.1 times as long as wide and with about 48 very long marginal setae. Ovipositor 0.7 times length of metatibia.

Male (paratype, Fig. 83). Body length 0.843 mm. Similar to female except for the normal sexually dimorphic features such as antenna and genitalia, and the following. Antenna (Fig.



Figs. 83–84. *Mymar alishan*, male (paratype): 83. Habitus; 84. Wings (arrow points to hind wing).

82) with scape (minus short radicle) 8.0 times as long as wide and longer than any flagellar segment, flagellar segments very long, much longer than wide. Protarsus 1.3 times as long as metatarsus. Fore wing (Fig. 84) with disc 4.5 times as long as wide, densely setose and with about 57 long marginal setae; apical dark area notably shorter than in the female. Hind wing (Fig. 84) with disc reduced to a narrow, short membrane and with 3 long marginal setae.

Diagnosis. *M. alishan* belongs to the informal *pulchellum* species group of *Mymar* Curtis, 1829, as defined by Donev & Triapitsyn (2010), and is very distinctive as it has the entire disc of the fore wing setose in both sexes, particularly densely so on the apical dark area (Figs. 80 and 84). Like in *Mymar maritimum* Triapitsyn and Berezovskiy, 2001 and *Mymar venustum* Girault, 1911 (Donev & Triapitsyn 2010), its hind wing is abbreviated to a short stub beyond the hamuli in the female (Fig. 81) but has a reduced membrane with several long marginal setae in the male (Fig. 84). In Triapitsyn & Berezovskiy (2001), female of *M. alishan* keys to couplet 4 together with *M. maritimum* and *Mymar pulchellum* Curtis, 1832 while its male keys to couplet 12 together with *Mymar ermak* Triapitsyn and Berezovskiy, 2001 and *Mymar cincinnati* Girault, 1917, which is now a synonym of *M.*

venustum (Donev & Triapitsyn 2010). Female of *M. venustum* is very similar to that of *M. pulchellum* (because intraspecific variability in the length of antennal segments in the species of *Mymar* can often be quite significant, particularly of F2, their proportions should be used with caution), so for the time being only males of these two species can be separated with confidence in the Nearctic region where both of them occur. The record of *M. venustum* (females only) from Andaman and Nicobar Islands, India, by Amer *et al*. (2017) needs confirmation because it is highly unlikely that this Nearctic species would occur there.

An updated key to the described species of *Mymar* in the world follows, as it is needed after two new species were added to the knowledge of the genus since the key by Triapitsyn & Berezovskiy (2001) was published (Hayat *et al*. 2008; Donev & Triapitsyn 2010), and other changes in its taxonomy were made by Donev & Triapitsyn (2010). The key does not include the four species recently described from India in Amer *et al*. (2017) based on one sex only (females) because their type specimens have not been examined and there is no information about their males, which are almost equally important for accurate recognition of *Mymar* species. Based on their original descriptions and illustrations, none of them is conspecific with *M. alishan* as all have a distinct glabrous area on the fore wing disc (Amer *et al*. 2017).

Triapitsyn & Berezovskiy (2001) incorrectly identified three females from Chiang Mai, Thailand as *Mymar schwanni* Girault, 1912; in fact, these and other specimens from several countries in the Oriental region including India (Manickavasagam *et al*. 2011) belong to a species from the *pulchellum* group whose identity remains to be figured out, although they are definitely more similar to *M. pulchellum* in having the hind wing with a distinct, albeit short, stub beyond the hamuli (Huber & Islam 2017, p. 88, Fig. 25). They are almost definitely conspecific either with specimens from Bangladesh and India which were identified, respectively, by Huber & Islam (2017) and Amer *et al*. (2017) as *M. pulchellum*, or with one of the four new species of *Mymar* described in Amer *et al*. (2017). In specimens of *M. schwanni* of both sexes from Australia, the hind wing either lacks such a stub beyond the hamuli (Fig. 87) or it is extremely short and indistinct (Fig. 88).

Key to the world species of *Mymar* (excluding four species from India described in Amer *et al*. (2017); male of *Mymar roopum* Hayat and Khan, 2008 is unknown)

1 Female: flagellum clavate, consisting of 6-segmented funicle and an entire clava (as in Figs 79, 92) ··························· 2
– Male: flagellum filiform, 11-segmented (as in Fig. 82) ······························ 12
2(1) Hind wing either abbreviated to a short stub just beyond the hamuli (as in Figs. 81, 89, 93) or such stub absent (Fig. 87) or indistinct (Fig. 88) (*pulchellum* species group) ·····································3
– Hind wing either filamentous or with a narrow expansion of membrane beyond the hamuli ····································· 8
3(2) Apical dark area on fore wing disc usually covering more than half of its length; hind wing without a distinct stub beyond the hamuli (Figs. 87–88) ·········· ··················· *M. schwanni* Girault, 1912
– Apical dark area on fore wing disc covering at most half of its length; hind wing with a distinct, albeit short, stub beyond the hamuli (its length varies) ····· ·· 4
4(3) Fore wing disc entirely setose (Fig. 80) ··············*M. alishan* Triapitsyn, sp. nov.
– Fore wing disc only partially setose ···· 5
5(3) Ratio of post hamuli stub length to length of entire hind wing at least 0.3:1 ······*Mymar ramym* Donev and Triapitsyn, 2010
– Ratio of post hamuli stub length to length of entire hind wing at most 0.2:1 ·· 6
6(5) Apical dark area on fore wing disc cov-

ering almost half of its length (Fig. 89); fore wing disc at most 3.5 times as long as wide; pedicel slightly shorter than F1 ……*M. maritimum* Triapitsyn and Berezovskiy, 2001

– Apical dark area on fore wing disc covering notably less than half of its length; fore wing disc at least 4.1 times as long as wide; pedicel either slightly longer than or about as long as F1 ……………… 7

7(6) Scape usually notably shorter than F2 ………………… *M. pulchellum* Curtis, 1832

– Scape at most slightly shorter than F2 (Fig. 92) …… *M. venustum* Girault, 1911

8(2) Hind wing filamentous beyond the hamuli, without apparent membrane and with 1 long apical seta ………………………… 9

– Hind wing with a narrow, but distinct, expansion of membrane beyond the hamuli and usually with several (but sometimes with only 1) long marginal setae ………………………………………… 10

9(8) F3 less than 3 times as long as wide, clava length at least 0.85 times combined length of F3–F6; only anterior half or so of apical dark area on fore wing disc setose ………………………………
……*Mymar taprobanicum* Ward, 1875

– F3 at least 3 times as long as wide, clava length at most 0.75 times combined length of F3–F6; most of anterior apical dark area on fore wing disc setose ………
……*M. roopum* Hayat and Khan, 2008

10(8) Fore wing disc entirely hyaline, without a dark apical area ……………………………
……*Mymar africanum* Annecke, 1961

– Fore wing disc with a distinct dark apical area …………………………………… 11

11(10) Most of apical dark area on fore wing disc setose ……………………………………
…… *M. ermak* Triapitsyn and Berezovskiy, 2001

– Only anterior half of apical dark area on fore wing disc setose ………………………
…… *Mymar regale* Enock, 1912

12(1) Hind wing either abbreviated to a short stub just beyond the hamuli or such stub absent or indistinct ……………………… 13

– Hind wing either filamentous or with a narrow expansion of membrane beyond the hamuli ………………………………… 15

13(12) Ratio of post hamuli stub length to length of entire hind wing at least about 0.3 : 1 ………………………………………
…… *M. ramym* Donev and Triapitsyn, 2010

– Post hamuli stub either absent or, if present, ratio of its length to length of entire hind wing at most 0.2 : 1 …… 14

14(13) Hind wing without a distinct stub beyond the hamuli ……………………………
…… *M. schwanni* Girault, 1912

– Hind wing with a distinct, albeit short, stub beyond the hamuli ……………………
…… *M. pulchellum* Curtis, 1832

15(12) Hind wing filamentous beyond the hamuli, without apparent membrane and almost always with 1 long apical seta (very rarely with two apical setae) …………… *M. taprobanicum* Ward, 1875

– Hind wing with a narrow, but distinct, expansion of membrane beyond the hamuli and with several long marginal setae (as in Figs. 84–86, 90–91) …… 16

16(15) Fore wing disc hyaline, without a dark apical area ……………………………………
…… *M. africanum* Annecke, 1961

– Fore wing disc with a distinct dark apical area …………………………………… 17

17(16) Fore wing disc entirely setose (Fig. 84) ………… *M. alishan* Triapitsyn, sp. nov.

– Fore wing disc not entirely setose ….18

18(17) Apical dark area on fore wing disc entirely setose (Fig. 86) ……………………
…… *M. ermak* Triapitsyn and Berezovskiy, 2001

– Apical dark area on fore wing disc not entirely setose, with at least a small but distinct bare area ……………………… 19

19(18) Fore wing disc less elongate, about 3.6 times as long as wide (Fig. 90) …………
…… *M. maritimum* Triapitsyn and Berezovs-

kiy, 2001

– Fore wing disc notably more elongate, about 4.4 times as long as wide ······· 20

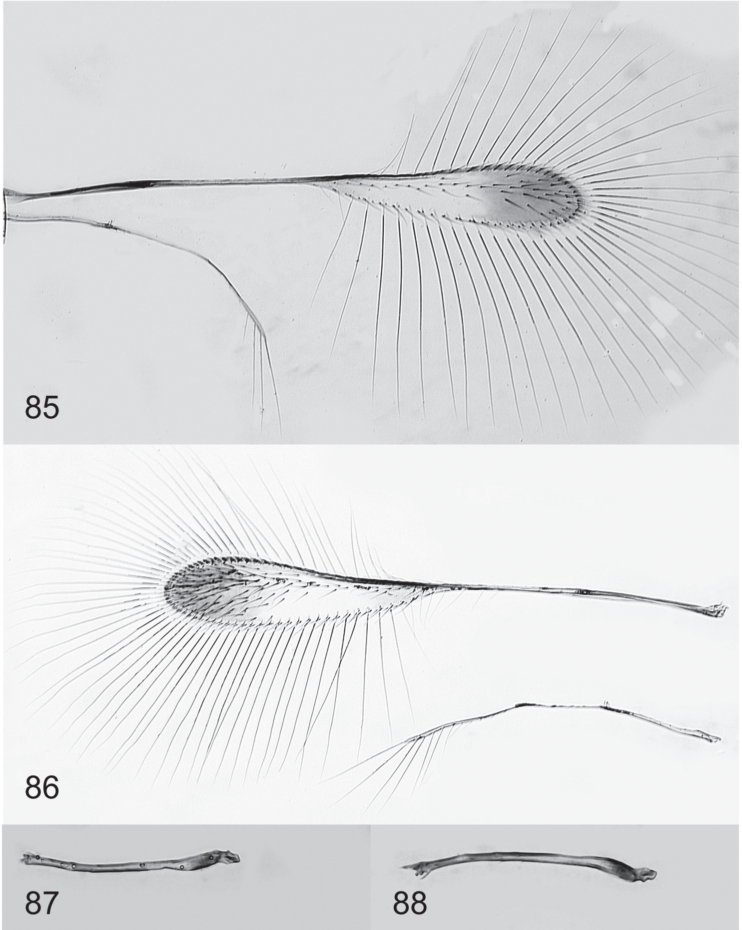
20(19) Apical dark area on fore wing disc with setae only in its anterior half (Fig. 91) ························*M. regale* Enock, 1912

– Apical dark area on fore wing disc with a few setae also in its posterior half (Fig. 85) ·····*M. venustum* Girault, 1911

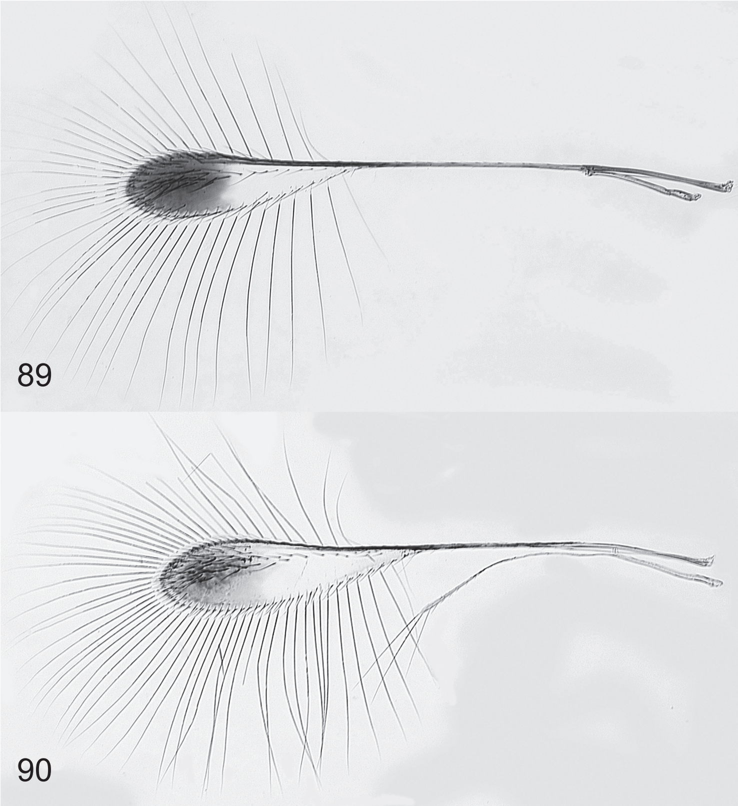
Etymology. The species is named after its type locality and is a noun in apposition.

Hosts. Unknown.

Comments. I have examined the following specimens of *M. schwanni*: Australia: Australian Capital Territory: Canberra, Black Mt., CSIRO, 35°16'S 149°06'E, G. A. P. Gibson: 1–7.ii.1999 (1 female, 1 male, UCRC); 15–21.iii.1999 (1 male, UCRC); 26.iv–2.v.1999 (1 female, 4 males, UCRC); 10–16.v.1999 (1 female, UCRC). Canberra Nature Park, Black Mt., Aranda Bushland, 35°15.89'S 149°05.08'E, 27–28.xi.2002, J. George, J. Munro, A. Owen (1 female, UCRC). New South Wales, Kosciuszko National Park, 35°54.9'S 148°37.3'E, 26–28.xi.2002, J. George, J. Munro, A. Owen, J. D. Pinto, G. Platner (2 males, UCRC). Queensland: Brisbane Forest Park: 27°20.28'S 152°46.12'E,



Figs. 85–88. *Mymar* spp.: 85. *Mymar venustum*, male fore and hind wings (holotype of *Mymar cincinnati*); 86. *Mymar ermak*, male fore and hind wings (paratype, Gornotayozhnoye, Ussuriyskiy rayon, Primorskiy kray, Russia); 87. *Mymar* schwanni, female hind wing (Mundubbera, Queensland, Australia); 88. *M. schwanni*, female hind wing (CSIRO, Black Mt., Canberra, Australian Capital Territory, Australia).



Figs. 89–90. *Mymar maritimum* (Gornotayozhnoye, Ussuriyskiy rayon, Primorskiy kray, Russia): 89. Female fore and hind wings (paratype); 90. Male fore and hind wings.

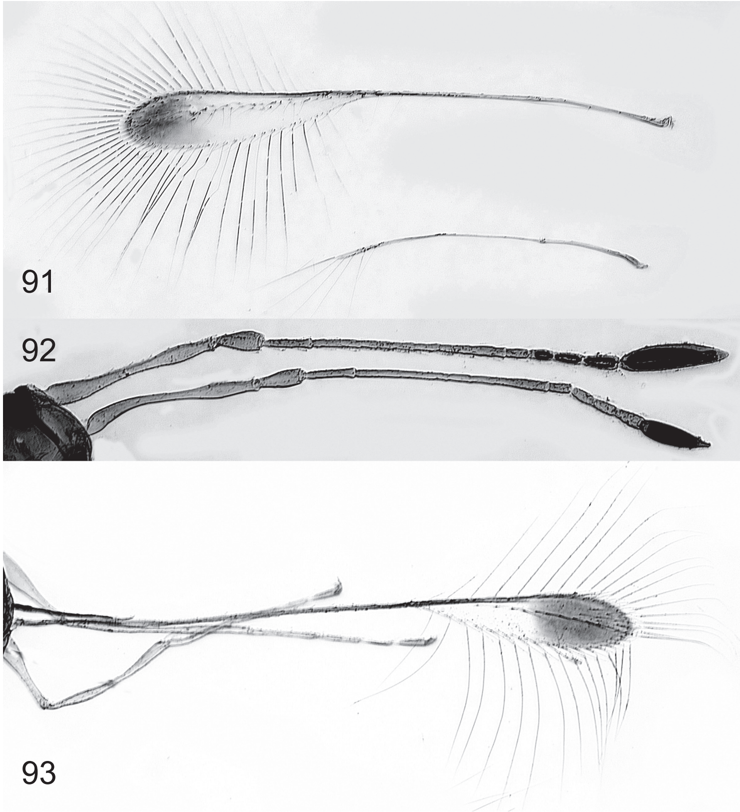
4–13.xii.2002, J. George, J. Munro, A. Owen (1 male, UCRC); 27°23.57'S 152°54.68'E, 5–6.xii.2002, J. George, J. Munro, A. Owen (1 male, UCRC); 27°24'04"S 152°49'48"E, 30.xii.1997, N. Power (1 female, CNC); 27°24.05'S 152°48.11'E, 4–13.xii.2002, J. George, J. Munro, A. Owen (1 female, UCRC). 9 km N of Crow's Nest, 14.iv.1990, J. M. Heraty (1 male, UCRC). Mundubbera, vi.2000, C. Freebairn (1 female, UCRC). South Australia, Picadilly Valley, 15.x.1992, L. S. and R. B. Kimsey (1 female, UCDC). Western Australia, Carters Rd. near Margaret R., 33°56.12'S 115°03.94'E, 15–16.xi.2002, J. George, D. Hawks, J. Munro, A. Owen (1 male, UCRC).

The following specimens of *M. venustum* have been examined: Canada, Ontario: Constance Bay, G. A. P. Gibson: 6–13.vii.1973 (1 male, CNC); 20.vii.1973 (1 male, CNC); 22–28.ix.1973 (1 female, CNC). Innisville, 22.viii.1963 (1 female, CNC). USA, New York, Seneca Co., 4.5 mi. SW of Lodi, Silver Thread Vineyard, 42°33'45.5"N 76°52'27.2"W, 202 m, 30.vii–14.viii.2010, G. Loeb, S.V. Triapitsyn (1 female, UCRC). This species is newly recorded from Canada.

Also, examined was the following specimen which mostly fits the original description of *M. roopum* except length of the clava is about 0.6 times the combined length of F3–F6: Philippines, Luzon Island, Quezon Prov., Mt. Benahaw de Lucban, 14°05.859'N 121°31.071'E, 747 m, 14–22.v.2011, H. Wood, M. Yngente (1 female, CAS).

***_Mymar maritimum_ Triapitsyn and Berezovskiy, 2001**

Material examined. Taiwan, Taipei City,



Figs. 91–93. *Mymar* spp.: 91. *Mymar regale*, male fore and hind wings (Corphalie, Antheit, Wanze, Liège, Belgium); 92. *Mymar venustum*, female antennae (holotype); 93. *M. venustum*, female fore and hind wings (holotype).

vii.1967, K. S. Lin (1 female, TARI).

***Mymar taprobanicum* Ward, 1875**

Mymar ?*indica* Mani, 1942: Lin, 1974: 95–96 [key, habitus illustration of a female (consistent with that of *M. taprobanicum*)], 99–100 (descriptive notes based on material from Taiwan).

M. taprobanicum Ward: Taguchi, 1974: 22 (Taipei).

Material examined. Taiwan: Chiayi Co., Chiayi: 11–13.xi.1956, K. S. Lin (4 males, TARI); 26.ix.1957, K. S. Lin (2 males, TARI); 18.vi.1972, K. S. Lin (1 female, TARI). Pingtung Co., Kenting National Park, Hengchun, Kueitzuchiao (as "Kuraru, Heng Chung"), 22–29.v.1965, K. S. Lin (2 males, TARI). Taichung: Taichung District Agricultural Improvement Station, 16.vii.1976, K. S. Lin, in rice field (1 male, TARI). Wufeng, TARI: 24°01'37.1"N 120°41'45.7"E, 83 m, 4–7.x.2016, S. V. Triapitsyn (1 male, UCRC); 24°01'52.4"N 120°41'34.2"E, 76 m, 6–11.x.2016, S. V. Triapitsyn, H.-T. Shih, Malaise trap in wild rice field (9 females, TARI; 11 females, UCRC). Taipei City: 2.viii.1950, K. S. Lin, "sweeping on rice seed bed" (2 males, TARI); vi.1967, K. S. Lin (1 male, TARI); vii.1967, K. S. Lin (1 male, TARI); viii.1967, K. S. Lin (1 male, TARI); vii.1969, K. S. Lin (2 males, TARI); x.1972, K. S. Lin (1 male, TARI); 1.x.1974, K. S. Lin (1 male, TARI).

Extralimital material examined. France: Côte-d'Or, Esbarres, 4.ix.1961, J. Barbier (1 female, MNHN). Var, Toulon, 1.v.1948, J. Barbier (1 female, 1 male, MNHN). Japan, Honshu Island, Yamaguchi Prefecture, Yamaguchi, 22.vii.1969, K. S. Lin, in rice field (1 male,

TARI).

Hosts in Taiwan. *N. lugens* (Stål, 1854) (Delphacidae) and *N. cincticeps* (Uhler 1896) (Cicadellidae) (Lin 1974).

Nepolynema grande **(Taguchi, 1971)**

N. grande (Taguchi): Triapitsyn, 2014a: 175 (Nantou Co.).

******Omyomymar breve*** **Lin and Chiappini, 1996**

Material examined. Taiwan, Orchid Island (Lan Yü), 3–8.iii.1991, C. K. Starr, H. Y. Wang (1 female, CNC).

******Omyomymar ?longidigitum*** **Lin and Chiappini, 1996**

Material examined. Taiwan, Taichung, Hsinkangshan (above Chengkung), 800 m, 17–22.iv.1998, A. Smetana, L. Robillard (1 female, CNC).

Comments. This female is very similar in most aspects to *O. longidigitum* Lin and Chiappini, 1996 from Fujian, China but has a relatively longer ovipositor. That, however, may be within an expected intraspecific variation because in many mymarids with very long ovipositors, their length can vary considerably.

******Omyomymar*** **spp.**

Material examined. Taiwan: Nantou Co.: Meifeng, 16.xii–16.i.1991, C. S. Lin (1 female, CNC). Zhushan, Shan Lin Xi, 1,600 m, 16.v.1990, L. LeSage (1 male, CNC). Orchid Island (Lan Yü): 3–8.iii.1991, C. K. Starr, H. Y. Wang (1 male, CNC); 200 m, 5–9.vii.1991, C. K. Starr (3 females, 1 male, CNC). Pingtung Co., Kenting National Park, C. K. Starr, S. M. Wu: 200 m, 17–23.v.1991 (3 males, CNC); 210 m, 29.v.1991 (1 male, CNC).

Comments. These specimens, which were determined to genus by Dr. John T. Huber, belong to several species, some of them likely undescribed.

******Ooctonus kokozai*** **Triapitsyn, sp. nov. (Figs. 94–103)**

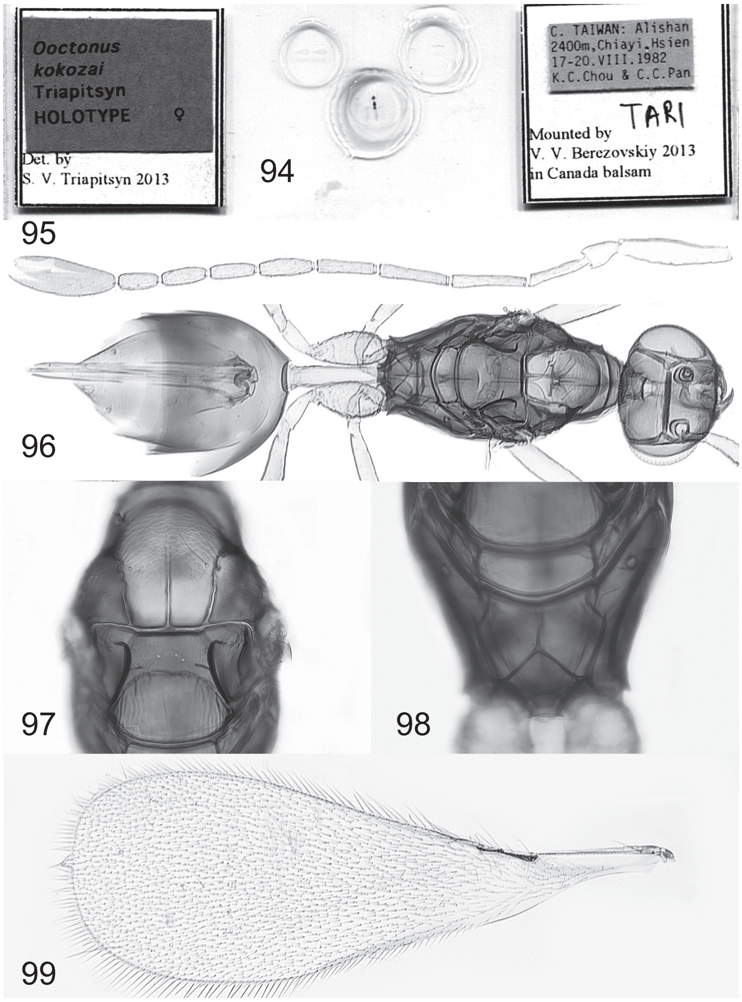
Type material. Holotype female (TARI) on slide (Fig. 94), labeled: 1. [orange] "C. TAIWAN: Alishan 2,400m, Chiayi Hsien 17–20.VIII.1982 K. C. Chou & C. C. Pan"; 2. "TARI Mounted by V. V. Berezovskiy 2013 in Canada balsam"; 3. [magenta] "*Ooctonus kokozai* Triapitsyn HOLOTYPE ♀"; 4. "Det. by S. V. Triapitsyn 2013." The holotype was remounted from a point; it is almost complete (missing one hind wing), dissected under 3 coverslips. Paratypes (all collected by sweeping and mounted on individual slides): Taiwan: Chiayi Co., Alishan: 2,450 m, 20–24.v.1956, K. S. Lin (1 male, TARI); 2,450 m (as "Mt. Ali"), 10–15.viii.1956, K. S. Lin (1 female, TARI); 2,450 m, 12–16.vi.1965, K. S. Lin (2 females, 1 male, TARI); 2,450 m, 16.vi.1965, K. S. Lin (9 females, 5 males, TARI; 1 female, 1 male, UCRC); 2,400 m, 5–9.viii.1981, L. Y. Chou, K. S. Lin (1 male, TARI).

Description. Female (holotype). Body (Fig. 96) mostly dark brown except mesoscutum apically and apical gastral terga brown, petiole light brown; scape and pedicel light brown, flagellum brown to dark brown; legs light brown except metafemur and metatibia brown.

Upper face with faint sculpture, lower face reticulate; vertex with faint cell-like sculpture.

Antenna (Fig. 95) long and slender, with radicle 0.28 times length of scape, remainder of scape 4.3 times as long as wide, a little wider medially than basally or apically, almost smooth; pedicel much shorter than F1; all funicular segments much longer than wide, among them F2 the longest and F8 the shortest; F1–F4 without mps, mps on F5 (2), F6 (1 on one antenna and 2 on the other), F7 (2), and F8 (2); clava 2.7 times as long as wide, a little shorter than scape (minus radicle), with 7 mps.

Mesosoma (Figs. 96–98) with pronutum lightly sculptured; midlobe of mesoscutum (Fig. 97) with a long median groove extending from its posterior margin to more than half length of mesoscutum; mesoscutum and anterior scutellum with conspicuous cell-like reticulate sculpture, frenum of scutellum with



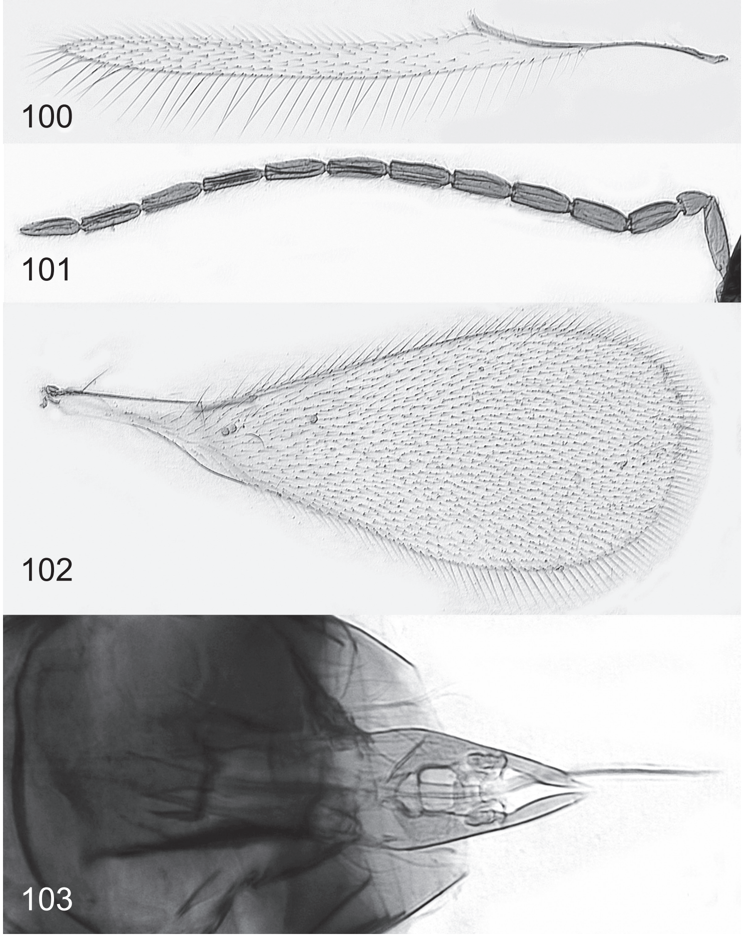
Figs. 94–99. *Ooctonus kokozai*, female (holotype): 94. Slide; 95. Antenna; 96. Body; 97. Mesoscutum and scutellum; 98. Dorsellum and propodeum; 99. Fore wing.

longitudinal cell-like sculpture on the sides and with faint, inconspicuous sculpture medially; metanotum smooth, with posterior margin slightly, broadly rounded; propodeum (Fig. 98) mostly smooth, with median (extending from basalmost point of the large pentagonal areole, formed by carinae at posterior margin of propodeum) carina short (much shorter than the areole) and almost extending to propodeal anterior margin; lateral carinae unifurcate, slightly diverging, almost extending to anterior margin of propodeum.

Fore wing (Fig. 99) 2.8 times as long as wide; disc with a slight brownish tinge throughout, densely setose (except bare behind base of submarginal vein), slightly truncate apically; longest marginal seta 0.2 times greatest width of wing. Hind wing (Fig. 100) 15.8 times as long as wide; disc with a slight brownish tinge and densely setose throughout (except for sparser setae and a small bare area just behind and beyond apex of venation); longest marginal seta 1.8 times greatest width of wing.

Pro- and meso-coxae smooth, metacoxa with light reticulate sculpture.

Petiole 4.1 times as long as wide, wider apically than basally, smooth, 1.2 times as



Figs. 100–103. *Ooctonus kokozai*: 100. Female hind wing (holotype); 101. Male antenna (paratype); 102. Male fore wing (paratype); 103. Male genitalia (paratype).

long as metacoxa. Gaster (Fig. 96) shorter than mesosoma; ovipositor rather long, occupying about 0.8 times length of gaster and notably exserted beyond apex of gaster (by 0.18 times total length of ovipositor), 0.95 times length of metatibia.

Measurements (mm) of the holotype. Body (of the slide-mounted specimen) 1.476; head 0.234; mesosoma 0.572; petiole 0.097; gaster 0.498; ovipositor 0.504. Antenna: scape (minus radicle) 0.181; pedicel 0.055; F1 0.094; F2 0.121; F3 0.115; F4 0.096; F5 0.088; F6 0.073; F7 0.073; F8 0.066; clava 0.17. Fore wing 1.587 : 0.56; longest marginal seta 0.111. Hind wing 1.187 : 0.075; longest marginal seta 0.136. Metatibia 0.529.

Variation (paratypes). Body length (slide-mounted specimens) 0.99–1.3 mm. Scape (minus radicle) 4.8–5.0 times as long as wide; F1 only slightly longer than pedicel in small specimens, F5 rarely with just 1 mps (in small specimens), F6 usually without mps or, rarely, with 1 mps (in large specimens); clava 3.7–3.8 times as long as wide. Fore wing 2.4–2.5 times as long as wide, longest marginal seta 0.16–0.24 times greatest width of wing; hind wing 14.5–15.5 times as long as wide, longest marginal seta 1.8–1.9 times greatest width of wing. Ovipositor exserted beyond apex of gaster by 0.12–0.17 times total length

of ovipositor, 0.83–0.93 times length of metatibia.

Male (paratypes). Body length (slide-mounted specimens) 0.93–1.32 mm. Similar to female except for the normal sexually dimorphic features such as antenna and genitalia (Fig. 103), and the following. Antenna (Fig. 101) with scape (including radicle) 3.6–4.0 times as long as wide, flagellum dark brown; fore wing (Fig. 102) 2.5–2.6 times as long as wide.

Diagnosis. *O. kokozai* (particularly its female antenna) is most similar to *Ooctonus lapen* Triapitsyn, 2010 from Nepal, which, however, has the mesoscutum almost completely smooth and a different arrangement of the propodeal carinae, but it does not even remotely fit in any of the other described Oriental species of *Ooctonus* reviewed by Triapitsyn (2010). An update to the key to the Palaearctic species of *Ooctonus* by Triapitsyn (2010) follows, to accommodate this new species, whose high altitude type locality is within the Palaearctic ecozone, and also *Ooctonus huberi* Bai, Jin and Li, 2015 from Heilongjiang, China (Bai *et al*. 2015).

Key to species of *Ooctonus* in the Palaearctic region (females)

1 Brachypterous: wings strongly abbreviated, fore wing not extending beyond apex of gaster ······ *Ooctonus hemipterus* Haliday, 1833

– Macropterous: wings normal, fore wing extending beyond apex of gaster ········· 2

2(1) Entire head and mesosoma (including mesonotum and propodeum) with reticulate sculpture; fore wing rounded apically ········ *O. hemipterus* Haliday, 1833

– Head and mesosoma at most partially with reticulate or cell-like sculpture (metanotum and propodeum without); fore wing at least slightly truncate apically ········· 3

3(2) Mps present on both antennae only on F7 and F8 ········· 4

– Mps present on both antennae also on other funicular segments besides F7 and F8 ········· 5

4(3) Midlobe of mesoscutum with a median groove of variable length (from a very short one, just at posterior margin of mesoscutum, to a relatively long groove anteriorly narrowing and extending to about 0.5 times length of mesoscutum); frenum of scutellum with cell-like reticulate sculpture ······ *Ooctonus saturn* Triapitsyn, 2010

– Midlobe of mesoscutum without median groove; frenum of scutellum mostly smooth except for a light sculpture at lateral borders and sometimes also at anterior margin ······ *Ooctonus vulgatus* Haliday, 1833

5(3) Clava with 8 mps ········· 6

– Clava with 7 mps ········· 7

6(5) F3 with 1 mps at least on one of the antennae; ovipositor relatively longer (1.2–1.4 times length of metatibia), exserted beyond apex of gaster by 0.08–0.16 times total length of ovipositor ······ *Ooctonus lokomotiv* Triapitsyn, 2010

– F3 without mps on both antennae; ovipositor relatively shorter (1.0–1.2 times length of metatibia), just barely exserted beyond apex of gaster (by less than 0.07 times total length of ovipositor) ······ *Ooctonus insignis* Haliday, 1833

7(5) Midlobe of mesoscutum normally with a median groove of variable length [from a very short, narrow one, just at posterior margin of mesoscutum (rarely inconspicuous)], to a long groove anteriorly narrowing and extending almost up to 0.7 times length of mesoscutum) ········ 8

– Midlobe of mesoscutum without median groove ········· 11

8(7) Propodeum with each of lateral carinae splitting anteriorly in two short, bifurcate (broadly Y-shaped) carinae and not extending to anterior margin of propodeum ··· *Ooctonus orientalis* Doutt, 1961

– Propodeum with each of lateral carinae either entire, not splitting anteriorly or, if not straight, then not bifurcate, and

extending (or almost extending) to anterior margin of propodeum ··················9

9(8) F4 without mps ······························ 10

– F4 with at least 1 mps (usually with 2 mps) ·· ······*Ooctonus tretiakovi* Triapitsyn, 2010

10(9) F6 with 2 mps; propodeum with lateral carinae straight ·································· ······*Ooctonus spartak* Triapitsyn, 2010

– F6 usually without mps or, sometimes, with 1 mps (except rarely, in the very large holotype, with 2 mps on just one of the antennae); propodeum with lateral carinae unifurcate (angulate) anteriorly (Fig. 98) ··· ······*O. kokozai* Triapitsyn, sp. nov.

11(7) Mps present on F5, F7 and F8 (F6 without mps) ·· ······*Ooctonus notatus* Walker, 1846

– Mps normally present at least on F5–F8 (F6 with at least 1 mps, usually with 2, except very rarely F6 without mps in some *Ooctonus sublaevis* Foerster, 1847 [in that case propodeum with median (extending from basalmost point of usually small pentagonal areole, formed by carinae at posterior margin of propodeum, to anterior margin of propodeum) carina usually longer than (or sometimes subequal in length to) the areole, or often median carina incomplete, not extending to anterior margin of propodeum, or almost absent]) ················· 12

12(11) F4 with 2 mps ·······························13

– F4 normally without mps or, if very rarely F4 with 1 mps (in some *O. sublaevis*), then propodeum with median carina usually longer than (or sometimes subequal in length to) the areole, or often median carina incomplete, not extending to anterior margin of propodeum, or almost absent ·················· 14

13 (12) Propodeum with median areole separated from dorsellum by a median carina; gaster light brown, contrastingly lighter than mesosoma; ovipositor relatively longer, at least 1.1 times as long as metatibia ·· ······ *Ooctonus novickyi* Soyka, 1950

– Propodeum with median areole abutting dorsellum (median carina absent); gaster brown, not contrastingly lighter than mesosoma; ovipositor relatively shorter, at most 0.9 times as long as metatibia ·· ······ *O. huberi* Bai, Jin and Li, 2015

14(12) Propodeum with median carina usually longer than (or sometimes subequal in length to) the areole, or often median carina incomplete, not extending to anterior margin of propodeum, or almost absent ······· *O. sublaevis* Foerster, 1847

– Propodeum with large pentagonal areole (formed by carinae at posterior margin of propodeum) extending to or almost to anterior margin of propodeum, thus median carina practically absent (or very short) ··························· ······ *Ooctonus us* Triapitsyn, 2010

Etymology. The new species is named in honor of my friend and fellow entomologist Dr. Vladimir Anatol'evich Kokoza (Department of Entomology, University of California, Riverside, USA), a well-known specialist in transgenic mosquitoes.

Hosts. Unknown.

***_Ooctonus notatus_ Walker, 1846**

Material examined. Taiwan, Pihu (1 km E of Taipei on highway to Zlan), 10.ii.1972, T. Z. Maa (1 female, TARI).

***_Ooctonus ?us_ Triapitsyn, 2010**

Material examined. Taiwan, Wulai (20 km S of Taipei City), 20.iii.1963, K. S. Lin (1 female, TARI).

***_Palaeoneura ?hishimoni_ (Taguchi, 1975)**

Material examined. Taiwan, Tsaoshan (20 km N of Taipei City), 19.v.1963, K. S. Lin (1 female, TARI).

***Palaeoneura tayalum* (Taguchi, 1975)**

Chaetomymar tayalum Taguchi 1975: 113–114 (Fenchihu, Chiayi Co.; holotype female lost from EUMJ).

P. tayalum (Taguchi): Triapitsyn and Aquino, 2010: 76.

Comments. Unfortunately, a good match to *P. tayalum* is lacking among several unidentified specimens of *Palaeoneura* from Taiwan in TARI, all poorly mounted on slides, so no neotype could be designated here for this taxon.

***Palaeoneura* spp.**

Material examined. Taiwan: Changhua Co.: Changhua City, x.1967, K. S. Lin (1 female, TARI). Xihu, x.1967, K. S. Lin (1 female, TARI). Yuanlin City, 2.ix.1967, K. S. Lin (1 male, TARI). Chiayi Co., Alishan, 2,450 m, 12–16.vi.1965, K. S. Lin (4 females, 2 males, TARI). Kaohsiung, Kuanshan Trail at Kuanshanchi River, 2,400 m, 20–23.vii.1993, A. Smetana (1 female, CNC). Pingtung Co., Kenting National Park, Hengchun, Kueitzuchiao (as "Kuraru, Heng Chung"), 22–29.v.1965, K. S. Lin (2 females, TARI). Taipei City: 1–12. vii.1963, K. S. Lin (1 female, TARI); 15–30. ix.1963, K. S. Lin (1 female, TARI); 21–31. v.1964, K. S. Lin (1 female, TARI); x.1972, K. S. Lin (1 female, TARI).

Comments. Among these, I was able to recognize several morphospecies belonging to the group of species which corresponds to the former genus *Chaetomymar* Ogloblin, 1946, as defined by Triapitsyn & Berezovskiy (2007, p. 42). At least three of those are undoubtedly new species; one of them (females from Kenting National Park and Taipei City) is characterized by a very long, strongly exserted ovipositor. Another undescribed species from the third species group of *Palaeoneura*, as defined by Triapitsyn and Berezovskiy (2007, p. 42), is from Alishan.

******Platystethynium glabrum*** **Jin and Li, 2016** (Fig. 104)

Material examined. Taiwan, Pingtung Co., Kenting National Park, 210–230 m, 5.v.1991, C. K. Starr, S. M. Wu, pan trap in secondary forest (1 female, CNC).

Comments. This specimen (Fig. 104), which was determined to genus by Dr. John T. Huber, fits well the original description of *P. glabrum*, described based on a single specimen (the holotype female) from Yunnan, China (Jin & Li 2016) without examination of the type series of the type species of the genus *Platystethynium* Ogloblin, *P. onomarchicidum* Ogloblin, 1946 from Java Island, Indonesia (Ogloblin 1946). Thus, the diagnosis in the original description of *P. glabrum* contains several incorrect statements about its differences from *P. onomarchicidum*, particularly about pelocity of the eyes (identically absent in both species), proportions of the antennal segments (about the same or within an expected intraspecific variation), and relative length of the propodeum (about the same). The only potentially significant difference between these two nominal taxa is the relative length of the ovipositor, which is about 1.8 times length of metatibia in *P. glabrum* but about 3.0 times in *P. onomarchicidum*. Otherwise, they are very similar in all other morphological features including the shape and proportions of the fore wing (about 9.6 times as long as wide in the holotype of *P. glabrum* and about 10.0 times in *P. onomarchicidum*). Without having at hand a good number of freshly collected specimens and the supporting molecular data, it is difficult to figure out whether these differences in the relative ovipositor length are due to intraspecific (that would probably be a more likely scenario) versus interspecific variation. I have examined 3 dry-mounted non-type females of *P. onomarchicidum* that have the same data as the female holotype and 32 female paratypes of this species (mounted on 2 slides). These non-type specimens, which are identically labeled: 1. "INDONESIA, Java Buitensorg, V-1939 C. Franssen"; 2. "ex. *Onomarchus uninotatus* (Audinet-Serv.)," had been borrowed from the National Museum of Natural History, Washington, District of Colum-

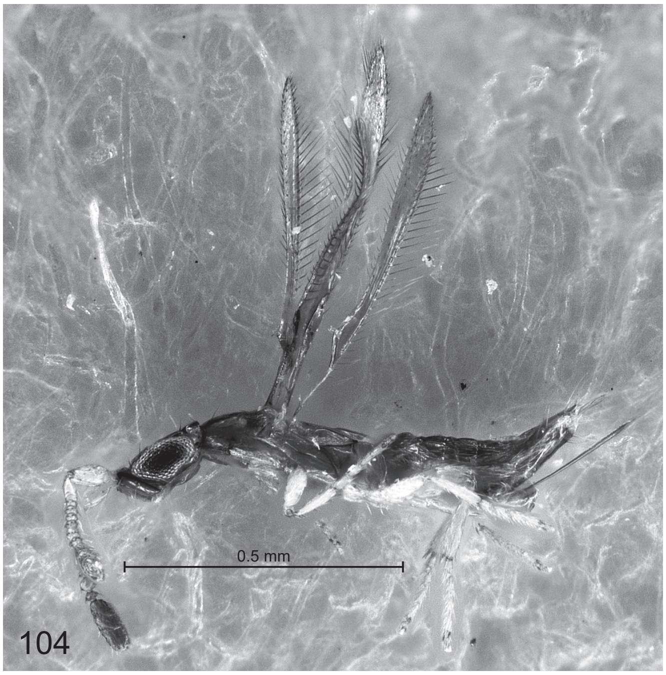


Fig. 104. *Platystethynium glabrum*, female (Kenting National Park, Pingtung Co., Taiwan): habitus in lateral view.

bia, USA (USNM), and one of them was then slide-mounted in Canada balsam at UCRC. The type locality of this species is Bogor (West Java Province, Java Island). Illustrated here, to facilitate its recognition, are an antenna (Fig. 105), body (Fig. 106), fore (Fig. 107) and hind (Fig. 108) wings of the slide-mounted female of *P. onomarchicidum*. Also examined was a specimen of *Platystethynium* sp. which in most regards fits *P. glabrum* but has a relatively broader fore wing (about 8.1 times as long as wide), and whose ovipositor is 2.3 times as long as metatibia: Thailand, Chiang Mai, Toong Tha Tam, Amphur Mae Wang, 1–10.x.1997, S. Sonthichai (1 female, UCRC).

***Polynema* (*Doriclytus*) sp.**

Material examined. Taiwan, Chiayi Co., Alishan, 2,450 m, 16.vi.1965, K. S. Lin (1 female, TARI).

***Polynema* (*Dorypolynema*) *mendeli* Girault, 1913**

Material examined. Taiwan: Chiayi Co., Chiayi, 26.ix.1957, K. S. Lin (2 females, 1 male, TARI). Taipei City, 6.viii.1960, K. S. Lin, "sweeping on rice seed bed" (1 female, TARI). Tsaoshan (20 km N of Taipei City), 14.viii.1958, K. S. Lin (1 female, TARI).

***Polynema* (*Dorypolynema*) sp.**

Material examined. Taiwan, Taipei City, 1–15.x.1963, K. S. Lin (1 female, TARI).

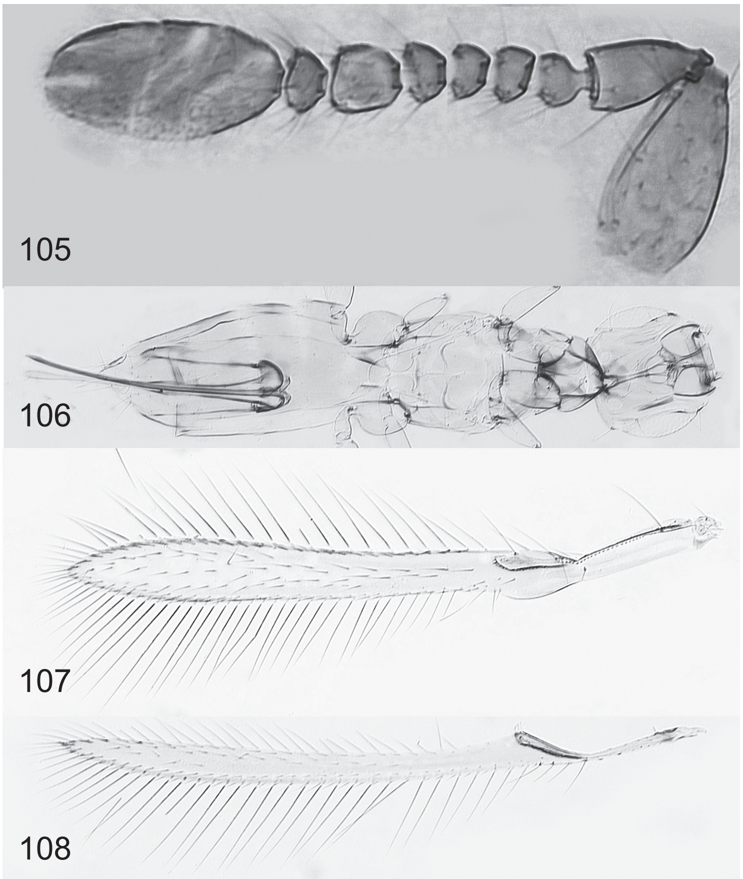
Comments. This specimen undoubtedly represents a new, undescribed species which is larger and darker than *P.* (*Dorypolynema*) *mendeli*, and also has a much wider fore wing.

***Polynema* (*Polynema*) sp(p).**

Material examined. Taiwan, Chiayi Co., Alishan, 2,450 m: 20–24.v.1956, K. S. Lin (1 female, TARI); 12–16.vi.1965, K. S. Lin (52 females, 11 males, TARI).

***Stephanocampta* sp.**

Material examined. Taiwan, Nantou Co., E of Shankan, 2,000–2,200 m, 28.v.1990, J. M. Heraty (1 female, CNC, determined by J. T.



Figs. 105–108. *Platystethynium onomarchicidum*, female (Bogor, West Java, Java Island, Indonesia): 105. Antenna; 106. Body; 107. Fore wing; 108. Hind wing.

Huber).

Comments. This interesting specimen represents an undescribed species, in which F2 of the female antenna is about as long as F3.

***Stephanodes reduvioli* (Perkins, 1905)**

Stephanodes orientalis Taguchi, 1978: 75 (Taipei).

Material examined. Taiwan: Chiayi Co., Alishan, 2,450 m, 16.vi.1965, K. S. Lin (1 female, TARI). Pingtung Co., Pingtung, 10.iii.1970, K. S. Lin, in rice field (1 female, TARI). Taichung, Taichung District Agricultural Improvement Station, 16.vii.1976, K. S. Lin, in rice field (2 females, TARI). Taipei: 1.x.1974, K. S. Lin (1 female, TARI); 8.x.1974, K. S. Lin (1 male, TARI).

Extralimital material examined. Japan, Honshu Island, Yamaguchi Prefecture, Yamaguchi, 22.vii.1969, K. S. Lin, sweeping in rice field (2 females, TARI).

***Stethynium sp.**

Material examined. Taiwan: Pingtung Co., Kenting National Park: 210–230 m, 5.v.1991, C. K. Starr, S. M. Wu (1 female, CNC); 200 m, 17–23.v.1991, C. K. Starr, S. M. Wu (2 females, CNC). Taipei City, City Park, 1–19.xii.1990, J. T. Chao (1 male, CNC).

Comments. These specimens, determined to genus by Dr. John T. Huber, may belong to *Stethynium triclavatum* Enock, 1909 but I am reluctant to make a positive identification because taxonomy of non-Holarctic species of

the genus *Stethynium* Enock, 1909 is currently in disarray.

***Zeyanus kweishuilini* Triapitsyn, 2016**

Z. kweishuilini Triapitsyn in Triapitsyn *et al.* 2016: http://dx.doi.org/10.1080/00305316.2016.1263246, published online 9.xii.2016 (Kenting National Park, Pingtung Co.); Triapitsyn *et al.*, 2017: 147 (illustrations), 149–154, 158 (key) (printed version).

***Zeyanus shihi* Triapitsyn, 2016**

Z. shihi Triapitsyn in Triapitsyn *et al.* 2016: http://dx.doi.org/10.1080/00305316.2016.1263246, published online 9.xii.2016 (Kenting National Park, Pingtung Co.); Triapitsyn *et al.*, 2017: 148 (illustrations), 154–155, 158 (key) (printed version).

ACKNOWLEDGMENTS

I thank Dr. Hsien-Tzung Shih (TARI) for valuable advice, friendly help, hospitality, and also for kindly translating the abstract into Chinese. Dr. John T. Huber (CNC) generously made available the important specimens determined by him to the genera many of which have not been known from Taiwan, and Drs. Chi-Feng Lee (TARI), Michael W. Gates (USNM), and Robert L. Zuparko (CAS) gave access to the collections under their care and arranged loans of specimens. Drs. Toshiharu Mita and Kazunori Matsuo (Kyushu University, Fukuoka, Japan) provided important information on the voucher specimens which were supposed to be deposited in the KUEC. Dr. Simon van Noort (Iziko Museums of South Africa, Cape Town, South Africa) made available to me digital images of the male paratype of *E. orientalis*, and Dr. Sagadai Manickavasagam (Parasitoid Taxonomy and Biocontrol Laboratory, Department of Entomology, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India) provided a photograph of the fore wing of the female paratype of *E. scutatus*. Mr. Vladimir V. Berezovskiy (UCRC) made excellent slide mounts of selected specimens.

REFERENCES

Aishan, Z., S. V. Triapitsyn, M. Xu, N.-q. Lin, and H.-y. Hu. 2016. Review of *Cosmocomoidea* (Hymenoptera: Mymaridae) from China, with descriptions of two new species. Zootaxa 4085:525–535.

Amer, F. S. K., S. B. Zeya, and K. Veenakumari. 2017 (2016). A review of the Indian species of *Mymar* Curtis (Hymenoptera: Mymaridae). J. Insect Syst. 3(1–2):16–37.

Anwar, P. T., S. B. Zeya, and S. U. Usman. 2015. A new species of *Alaptus* with notes on *Eubroncus* species from India (Hymenoptera: Mymaridae). J. Insect Syst. 2:24–34.

Bai, H. F., X. X. Jin, and C. D. Li. 2015. A taxonomic study of *Ooctonus* (Hymenoptera, Mymaridae) from Heilongjiang, China. ZooKeys 479:25–36.

Chen, B. H. 1993. Occurrence and preference of *Anagrus incarnatus* Haliday (Hymenoptera: Mymaridae) on eggs of two rice planthoppers in Taiwan. Plant Prot. Bull. 35:267–275.

Chen, B. H. and J. Z. Yu. 1989. *Anagrus incarnatus* Haliday, a new record from eggs of brown planthopper in Taiwan. J. Agric. Res. China 38:458–462.

Chiappini, E., S. V. Triapitsyn, and A. Donev. 1996. Key to the Holarctic species of *Anagrus* Haliday (Hymenoptera: Mymaridae) with a review of the Nearctic and Palaearctic (other than European) species and descriptions of new taxa. J. Nat. Hist. 30:551–595.

Chu, Y. I. and Y. Hirashima. 1981. Survey of Taiwanese literature on the natural enemies of rice leafhoppers and planthoppers. Esakia 16:33–37.

Donev, A. D. and S. V. Triapitsyn. 2010. A new species of *Mymar* (Hymenoptera: Mymaridae) from the Palaearctic region, with nomenclatural changes in the genus. Zootaxa 2644:64–68.

Doutt, R. L. 1955. Hymenoptera: Trichogrammatidae and Mymaridae. Insects Micronesia 19:1–17.

Gibson, G. A. P. 1997. Morphology and terminology, p.16–44. *in*: Annotated Keys to the Genera of Nearctic Chalcidoidea (Hymenoptera). (Gibson, G. A. P., J. T. Huber, and J. B. Woolley, eds.) NRC Research Press. Ontario, Canada, 794 pp.

Hayat, M., S. B. Anis, and F. R. Khan. 2008. Descriptions of two new species of Mymaridae (Hymenoptera: Chalcidoidea) from India, with some records. Orient. Insects 42:327–333.

Hayat, M. and F. R. Khan. 2009. First record of *Eubroncus* from India (Hymenoptera: Chalcidoidea: Mymaridae), with description of a new species. J. Threat. Taxa 1:439–440.

Hirashima, Y. 1981. Field studies on the biological control of leafhoppers and planthoppers (Hemiptera: Homoptera) injurious to rice plants in South-East Asia. An account for the year 1979. Esakia 16:1–4.

Huber, J. T. 2003. Review of *Chaetomymar* Ogloblin, with description of a new species in the Hawaiian Islands (Hymenoptera: Mymaridae). J. Hymenopt. Res. 12:77–101.

Huber, J. T. and N. Islam. 2017. Introduction to the Mymaridae (Hymenoptera) of Bangladesh. ZooKeys 675:75–96.

Jin, X. X. and C. D. Li. 2014. First record of *Eubroncus* (Hymenoptera, Mymaridae) from China, with description of three new species. ZooKeys 399:29–41.

Jin, X. and C. Li. 2016. First report of *Platystethynium* with description of a new species and two other new records from China (Hymenoptera: Mymaridae). J. For. Res. 27:203–207.

Lin, K. J. 1974. Notes on some natural enemies of *Nephotettix cincticeps* (Uhler) and *Nilaparvata lugens* (Stål) in Taiwan. J. Taiwan Agric. Res. 23:91–115. (in Chinese with English abstract)

Lin, N. Q. and M. Xu. 2000. Key to genera of Mymaridae (Hym.: Chalcidoidea) known from China. J. Fujian Agric. Univ. 29:43–49. (in Chinese with English abstract)

Lin, N. Q. and M. Xu. 2003. Mymaridae, p.695–711. *in*: Fauna of Insects of Fujian Province of China. Vol. 7. (Huang, B. K., ed.) Fujian Publishing House of Science and Technology. Fujian, China. 927 pp. (in Chinese)

Manickavasagam, S., A. Rameshkumar, and K. Rajmohana. 2011. First report of four species of fairyflies from India, key to Indian species of four genera and additional distributional records of Mymaridae (Hymenoptera: Chalcidoidea). Madras Agric. J. 98(10–12):393–408.

Miura, T., Y. Hirashima, M. T. Chûjô, and Y. I. Chi. 1981. Egg and nymphal parasites of rice leafhoppers and planthoppers. A result of field studies in Taiwan in 1979 (Part 1). Esakia 16:39–50.

Narendran, T. C. and M. Anjana. 2013. A new record and a new species of *Australomymar* Girault (Hymenoptera: Mymaridae) from Vietnam with a key to species. J. Exp. Zool. India 16:435–439.

Ogloblin, A. A. 1946. Descriptions of new genera and species of Mymaridae (Hymenoptera: Chalcidoidea). Iowa St. Coll. J. Sci. 20:277–295.

Palanivel, S. and S. Manickavasagam. 2015. Description of a new species of *Eubroncus* Yoshimoto (Hymenoptera: Mymaridae) from India, with a key to world species. J. Threat. Taxa 7:7152–7156.

Rehmat, T. and S. B. Anis. 2014. Record of some species of Mymaridae from India (Hymenoptera: Mymaridae), with description of two new species. J. Insect Syst. 1:53–61.

Sahad, K. A. and Y. Hirashima. 1984. Taxonomic studies on the genera *Gonatocerus* Nees and *Anagrus* Haliday of Japan and adjacent regions, with notes on their biology (Hymenoptera, Mymaridae). Bull. Inst. Trop. Agric., Kyushu Univ. 7:1–78.

Schauff, M. E. 1981. A review of Nearctic species of *Acmopolynema* Ogloblin (Hymenoptera: Mymaridae). Proc. Entomol. Soc. Wash. 83:444–460.

Subba Rao, B. R. and M. Hayat. 1983. Key to the genera of Oriental Mymaridae, with a preliminary catalog (Hymenoptera: Chalcidoidea). Contrib. Amer. Entomol. Inst. 20:125–150.

Taguchi, H. 1972. Some new species of the genera *Camptoptera* and *Ptilomymar* from Bohol I., Philippines (Hymenoptera: Mymaridae). Kontyû 40:223–230.

Taguchi, H. 1974. Records of two *Mymar* species from Japan and Taiwan (Hymenoptera: Mymaridae). Trans. Shikoku Entomol. Soc. 12:22.

Taguchi, H. 1975. Two new *Chaetomymar* species from Japan and Taiwan (Hymenoptera: Mymaridae). Trans. Shikoku Entomol. Soc. 12:111–114.

Taguchi, H. 1977a. A new genus belonging to the tribe Mymarini from Japan, Taiwan and Malaysia (Hymenoptera: Mymaridae). Trans. Shikoku Entomol. Soc. 13:137–142.

Taguchi, H. 1977b. Two new species of the genus *Camptoptera* from Taiwan (Hymenoptera: Mymaridae). Trans. Shikoku Entomol. Soc. 13:143–146.

Taguchi, H. 1978. A new species of the genus *Stephanodes* from Japan and Taiwan (Hymenoptera: Mymaridae). Trans. Shikoku Entomol. Soc. 14:73–76.

Thompson, W. R. 1958. A Catalogue of the Parasites and Predators of Insect Pests. Section 2: Host parasite catalogue. Part 5: Hosts of the Hymenoptera (Miscogasteridae to Trigonalidae), Lepidoptera and Strepsiptera. Imperial Parasite Service, Belleville, Canada. 698 pp.

Tian, H. X., N. Q. Lin, and J. Lin. 2006. Preliminary analysis of generic diversity of Trichogrammatidae and Mymaridae from 10 provinces of China. J. Fujian Agric. For. Univ. (Nat. Sci. Ed.) 35:480–485. (in Chinese)

Triapitsyn, S. V. 2002. Species-level taxonomy of Mymaridae (Hymenoptera): Current status and im-

plications for biological control of leafhoppers of economic importance. p.89–94. *in*: Parasitic Wasps: Evolution, Systematics, Biodiversity and Biological Control. (Melika, G. and C. Thuróczy, eds.) Agroinform Kiadó és Nyomda Kft. Budapest, Hungary. 480 pp.

Triapitsyn, S. V. 2010. Revision of the Palaearctic species and review of the Oriental species of *Ooctonus* (Hymenoptera: Mymaridae), with notes on extralimital taxa. Zootaxa 2381:1–74.

Triapitsyn, S. V. 2013a. A new species of *Anagrus* (Hymenoptera: Mymaridae) from Tahiti, with notes on egg parasitoids of proconiine sharpshooters (Hemiptera: Cicadellidae: Proconiini) in the world. J. Taiwan Agric. Res. 62:289–299.

Triapitsyn, S. V. 2013b. Review of *Gonatocerus* (Hymenoptera: Mymaridae) in the Palaearctic region, with notes on extralimital distributions. Zootaxa 3644:1–178.

Triapitsyn, S. V. 2013c. Taxonomy and biology of egg parasitoids of Auchenorrhyncha of economic importance in Taiwan and adjacent countries, and of proconiine sharpshooters in the New World. p.123–144. *in*: Proceedings of the 2013 International Symposium on Insect Vectors and Insect-Borne Diseases. August 6–8, 2013. Taichung, Taiwan. Taiwan Agric. Res. Inst., Taichung, Taiwan.

Triapitsyn, S. V. 2014a. *Nepolynema*, a new genus of Mymaridae (Hymenoptera: Chalcidoidea), and its two new species from Costa Rica and Papua New Guinea. Proc. Russian Entomol. Soc. 85:170–182.

Triapitsyn, S. V. 2014b. Revision of the genus *Camptoptera* Foerster (Hymenoptera: Mymaridae) in the Palaearctic region, with taxonomic notes on some extralimital species. Far East. Entomol. 285:1–85.

Triapitsyn, S. V. 2015a. The genus *Himopolynema* (Hymenoptera: Mymaridae) in Taiwan and taxonomic comments on some extralimital species. Formosan Entomol. 35:79–116.

Triapitsyn, S. V. 2015b. Taxonomy of the genus *Anagrus* Haliday (Hymenoptera: Mymaridae) of the world: an annotated key to the described species, discussion of the remaining problems, and a checklist. Acta Zool. Lilloana 59:3–50.

Triapitsyn, S. V. 2016. Review of the Oriental species of the genus *Arescon* Walker, 1846 (Hymenoptera: Mymaridae). Euroasian Entomol. J. 15:137–151.

Triapitsyn, S. V. 2017a. Revision of *Alaptus* Westwood (Hymenoptera: Mymaridae) in the Holarctic region, with taxonomic notes on some extralimital species. Zootaxa 4279:1–92.

Triapitsyn, S. V. 2017b. Taxonomic notes on *Camptoptera* Foerster, 1856 (Hymenoptera: Mymaridae). Far East. Entomol. 332:7–18.

Triapitsyn, S. V., Z. Aishan, and H. Y. Hu. 2017. Descriptions of two new species of *Zeyanus* Huber (Hymenoptera: Mymaridae), with notes on some other congeneric taxa from the Oriental part of China. Orient. Insects 51:145–159.

Triapitsyn, S. V. and D. A. Aquino. 2010. On the occurrence of *Polynema* Haliday (*Dorypolynema* Hayat and Anis) and *Palaeoneura* Waterhouse (Hymenoptera: Mymaridae) in the New World, with description of two new species. Acta Zool. Lilloana 54:61–77.

Triapitsyn, S. V. and J. W. Beardsley. 2000. A review of the Hawaiian species of *Anagrus* (Hymenoptera: Mymaridae). Proc. Hawaiian Entomol. Soc. 34:23–48.

Triapitsyn, S. V. and V. V. Berezovskiy. 2001. Review of the Mymaridae (Hymenoptera, Chalcidoidea) of Primorskii krai: genus *Mymar* Curtis. Far East. Entomol. 100:1–20.

Triapitsyn, S. V. and V. V. Berezovskiy. 2002. Review of the Mymaridae (Hymenoptera, Chalcidoidea) of Primorskii krai: Genera *Anagroidea* Girault and *Eubroncus* Yoshimoto, Kozlov et Trjapitzin. Far East. Entomol. 114:1–17.

Triapitsyn, S. V. and V. V. Berezovskiy. 2004a. Review of the genus *Anagrus* Haliday, 1833 (Hymenoptera: Mymaridae) in Russia, with notes on some extralimital species. Far East. Entomol. 139:1–36.

Triapitsyn, S. V. and V. V. Berezovskiy. 2004b. Review of the genus *Litus* Haliday, 1833 in the Holarctic and Oriental regions, with notes on the Palaearctic species of *Arescon* Walker, 1846 (Hymenoptera, Mymaridae). Far East. Entomol. 141:1–24.

Triapitsyn, S. V. and V. V. Berezovskiy. 2007. Review of the Oriental and Australasian species of *Acmopolynema*, with taxonomic notes on *Palaeoneura* and *Xenopolynema* stat. rev. and description of a new genus (Hymenoptera: Mymaridae). Zootaxa 1455:1–68.

Triapitsyn, S. V. and J. T. Huber. 2000. 51 Fam. Mymaridae—Mymarids. p.603–614. *in*: Keys to the Insects of Russian Far East. Vol. 4. Neuropteroidea, Mecoptera, Hymenoptera, Part 4. (Lehr, P. A., ed.) Dal'nauka. Vladivostok, Russia. 650 pp. (in Russian)

Triapitsyn, S. V. and H. T. Shih. 2014. Egg parasitoids (Hymenoptera: Mymaridae and Trichogrammatidae) of *Kolla paulula* (Walker) (Hemiptera: Cicadellidae) in Taiwan. J. Asia-Pac. Entomol. 17:673–678.

Yoshimoto, C. M., M. A. Kozlov, and V. A. Trjapitzin. 1972. A new subfamily of Mymaridae (Hymenoptera, Chalcidoidea). Entomol. Obozr. 51:878–885. (in Russian)

台灣纓小蜂科 (膜翅目：小蜂總科) 名錄記述暨五新種描述

Serguei V. Triapitsyn[1,*]

摘要

Triapitsyn, S. V. 2018. 台灣纓小蜂科 (膜翅目：小蜂總科) 名錄記述暨五新種描述。台灣農業研究 67(2):113–165。

本文有關台灣產膜翅目纓小蜂科名錄，包括每物種的分布與寄主訊息，總計 28 屬 60 種，其中 13 屬 33 種為新紀錄，以及 *Acmopolynema berezovskiyi* sp. n., *Anagroidea montana* sp. n., *Camptoptera jthuberi* sp. n., *Mymar alishan* sp. n. 與 *Ooctonus kokozai* sp. n. 等 5 個新種。本文也將 *Eubroncus* Yoshimoto, Kozlov and Trjapitzin, 1972 之模式種—*Eubroncus orientalis* Yoshimoto, Kozlov and Trjapitzin, 1972，進行雄成蟲重新描述，並以採自印尼蘇拉威西島的一件雌成蟲標本，進行首次描述。隨文檢附 *Eubroncus* 屬的物種檢索表，其中 *Eubroncus hani* Jin and Li, 2014 為 *Eubroncus indicus* Hayat and Khan, 2009 的新異名，該物種係以採自尼泊爾的雄成蟲標本為描述依據；本文另就 *Cosmocomoidea tenuis* Xu, Lin and Hu, 2016 與 *Eubroncus tibetanus* Jin and Li, 2014，分別檢查來自台灣與日本的雄成蟲標本，進行描述。纓小蜂科為卵寄生蜂類，其某些成員為半翅目稻蝨科與葉蟬科等農業害蟲的重要天敵，在台灣之往昔記錄中對此等蟲種已有嚴謹之分析。

關鍵詞：纓小蜂科、名錄、新種、台灣、卵寄生蜂。

投稿日期：2017 年 6 月 1 日；接受日期：2017 年 10 月 27 日。

[*] 通訊作者：serguei.triapitsyn@ucr.edu
[1] 美國加州大學河濱分校昆蟲學系首席科學研究員。美國 河濱。

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):166–180 (2018)
DOI: 10.6156/JTAR.201806_67(2).0003

研究報告

柑橘銹蟎 [*Phyllocoptruta oleivora* (Ashmead)] 在三種柑橘上之族群動態與空間分布

陳柏宏 [1] 王泰權 [1] 陳祈男 [2] 黃瓊慧 [3] 黃守宏 [4,*]

摘要

陳柏宏、王泰權、陳祈男、黃瓊慧、黃守宏。2018。柑橘銹蟎 [*Phyllocoptruta oleivora* (Ashmead)] 在三種柑橘上之族群動態與空間分布。台灣農業研究 67(2):166–180。

柑橘銹蟎 (*Phyllocoptruta oleivora*) 為柑橘類作物的重要害蟎，以刺吸式口器吸食葉片或果實表皮，嚴重影響果實商品價值。本研究於 2016 年 1–12 月，調查柑橘銹蟎於尤利加檸檬 (‘Eureka’ lemon)、波斯萊姆 (‘Persian’ lime) 及茂谷柑 (‘Murcott’ tangor) 上的田間族群動態與空間分布。結果顯示，3 種柑橘品種中，以小果至大果期為柑橘銹蟎族群數量高峰期，且果實為銹蟎主要危害對象，老葉次之，新葉上的蟎數顯著較少。葉片上，又以葉背蟎數多於葉面。果樹不同方位發生的蟎數間，無明顯差異。此外，5–10 月的柑橘銹蟎密度極低，降雨量與降雨頻度為影響柑橘銹蟎田間族群密度的關鍵因子。空間分布分析上，分散指數 (index of dispersion)、平均擁擠度 (Lloyd’s index of mean crowding) 及聚集指數 (Lloyd’s index of patchiness) 皆顯示，柑橘銹蟎族群一般呈現聚集型分布，惟密度極低時則轉為均勻型或逢機型分布。

關鍵詞：柑橘銹蟎、族群動態、空間分布。

前言

柑橘銹蟎 [citrus rust mite, *Phyllocoptruta oleivora* (Ashmead)] 屬於蟎蜱亞綱 (Acari) 真蟎總目 (Acariformes) 前氣門目 (Prostigmata) 節蜱科 (Eriophyidae) 之節肢動物，為世界性柑橘類作物之重要害蟎，亦是台灣柑橘生產上的重要限制因子 (Lo 2006; Vacante 2009)。其分布範圍極廣，亞洲、美洲、非洲、歐洲及大洋洲地區皆可發現其蹤跡，偏好潮濕、溫熱的環境 (Lindquist *et al*. 1996)。寄主以芸香科 (Rutaceae) 之柑橘屬 (*Citrus*) 與金柑屬 (*Fortunella*) 植物為主，如橙類、寬皮柑類、柚類及金柑類等 (Yothers & Mason 1930)。柑橘銹蟎以刺吸式口器為害，葉片、枝條經取食後，常出現褐色小斑點 (Albrigo & McCoy 1974; Achor *et al*. 1991)，亦可能造成提早落葉現象 (McCoy 1976)。果實被害則會導致果皮木質素增生、表皮細胞內酚化物氧化，產生銹褐色或銹黑色的粗糙表皮。柑橘果實的徵狀也依受害程度與柑橘品種而異，例如，柚類上會呈特有的淚痕狀銹色斑塊；檸檬上則出現龜裂、斑駁的灰白色果皮 (Winston 1920; Griffiths & Thompson 1957; Albrigo & McCoy 1974; McCoy & Albrigo 1975)。此外，受害果的生長、重量、大小、落果率、果汁含量及成分亦會受到影響 (McCoy *et al*. 1976; Allen 1978, 1979a, 1979b; Yang *et al*. 1994)。

柑橘銹蟎可行孤雌產雄 (arrhenotokous parthenogenesis) 方式繁衍子代 (Vacante 2009)，

投稿日期：2017 年 7 月 25 日；接受日期：2017 年 9 月 19 日。
[*] 通訊作者：shhuang@dns.caes.gov.tw
[1] 農委會農業試驗所嘉義農業試驗分所植物保護系助理研究員。台灣 嘉義市。
[2] 農委會農業試驗所嘉義農業試驗分所園藝系助理研究員。台灣 嘉義市。
[3] 農委會農業試驗所嘉義農業試驗分所植物保護系研究助理。台灣 嘉義市。
[4] 農委會農業試驗所嘉義農業試驗分所植物保護系副研究員。台灣 嘉義市。

生長發育受多項環境因子影響，溫度為主要的因子之一，於室內定溫環境下，柑橘銹蟎於 29℃的發育速率最高 (Allen *et al*. 1995)，另有報告指出 30−32℃為銹蟎最佳發育溫度 (Ebrahim 2000)。因此，於較溫暖的夏季，柑橘銹蟎僅需 7−10 d 即可完成 1 個世代，於冬季則需 14 d 或更長時間 (Yothers & Mason 1930)。濕度亦會影響柑橘銹蟎發育，潮濕的環境 (尤其於雨後) 有利銹蟎族群增長 (Pratt 1957; Dean 1959)，但亦有研究指出，過多的雨水會導致若蟎死亡率增加且影響產卵行為 (Van Brussel 1975)。於多數柑橘類產區，柑橘銹蟎為終年發生，一年可發生幾十個以上之世代 (Van Brussel 1975; Vacante 2009; Al-Azzazy 2016)。柑橘銹蟎於不同地區、季節的族群密度變化亦不盡相同，如於佛羅里達州，柑橘銹蟎田間族群於 5−7 月逐漸增加，至 8 月下旬後則開始減少，但於 10−11 月上旬仍有回升之可能，全年以春、夏季為發生盛期 (Griffiths & Thompson 1957; Albrigo & McCoy 1974; Rogers & Stansly 2016)；在埃及，以 6−9 月為柑橘銹蟎密度高峰期，1−2 月及 12 月的密度則最低 (Al-Azzazy 2016)；而於哥斯大黎加 (Costa Rica) 的阿拉胡埃拉 (Alajuela) 省，柑橘銹蟎在晚崙西亞橙 (Valencia orange) 的發生盛期為 2 月、3 月及 5 月 (González *et al*. 1985)。

有關柑橘銹蟎於寄主株內棲息習性之研究報告甚多，但部分結果差異頗大。不少研究發現，柑橘銹蟎似乎為躲避陽光直射，偏好聚集於植株之遮陰處，且以半遮陰處的銹蟎密度較全遮陰處者為高 (Yothers & Mason 1930; Albrigo & McCoy 1974; McCoy & Albrigo 1975; Van Brussel 1975; Allen & McCoy 1979)。於葉片與果實之分布上，部分報告指出，葉背上蟎數普遍多於葉面 (Yothers & Mason 1930; Vacante 2009)，卻也有研究觀察到葉面蟎數顯著多於葉背 (Van Brussel 1975; Al-Azzazy 2016)，或兩者間無差異 (Aghajanzadeh & Mallik 2007)。當果實逐漸成熟時，果實上的柑橘銹蟎密度顯著高於葉片 (Yothers & Mason 1930; Albrigo & McCoy 1974; McCoy 1979; Aghajanzadeh & Mallik 2007; Vacante 2009)。於植株不同方位間，有學者發現柑橘植株北側之柑橘銹蟎數量較南側多 (Allen & McCoy 1979)，也有報告指出東側與北側的蟎數較多 (Dean 1959)，或單以東側蟎數最多 (Aghajanzadeh & Mallik 2007)。然而，依據 Van Brussel (1975) 之紀錄，卻以植株東側為四方位中蟎數最少者。不同高度間，植株底層的蟎數似乎較多 (Allen & McCoy 1979; Al-Azzazy 2016)，但仍有研究顯示不同高度間並無顯著差異 (Aghajanzadeh & Mallik 2007)。樹冠內外層間，則以樹冠外層的密度較高 (Vacante 2009)。

台灣地處亞熱帶地區，氣候溫暖且潮濕，各地柑橘產區多為柑橘銹蟎合適的棲所。由於瞭解病蟲害於田間之生態，係植物保護上重要的一環，若能深入瞭解柑橘銹蟎族群動態與分布，將利於掌握防治時機及達到經濟防治之成效。然而，國內有關此害蟎的研究報告不多，加上柑橘銹蟎的族群消長與棲息偏好，依地理環境或寄主植物而有甚大的差異 (Yothers & Mason 1930; Vacante 2009)，故難以國外研究準確預估銹蟎於台灣本土發生情形。因柑橘種類繁多，本研究針對較具有機栽培潛力之尤利佳檸檬與波斯萊姆，以及近年來經濟價值頗高的茂谷柑。以此三種柑橘為例，調查柑橘銹蟎於果園的族群動態與分布，找出銹蟎密度高峰期與影響族群變化之重要因子，希冀作為往後柑橘銹蟎整合性管理上之參考依據。

材料與方法

柑橘銹蟎取樣方法

田間取樣方法參照 Aghajanzadeh & Mallik (2007) 採用之膠帶黏貼法 (adhesive tape method)。此方法係以透明膠帶 (3.5 × 1.9 cm^2，四維企業股份有限公司) 平貼於柑橘果實或葉片上，利用膠帶黏性將植株表面的柑橘銹蟎粘黏取下，而後再將膠帶黏貼於載玻片以完成取樣。取樣後之膠帶中心位置標記 1 cm^2 正方形範圍，並利用解剖顯微鏡檢視該區域內之柑橘銹蟎的若、成蟎總數量。

柑橘銹蟎於果園之族群動態

柑橘銹蟎族群動態調查之柑橘品種共 3 種，分別為尤利佳檸檬 (*Citrus* × *limon* 'Eureka') (簡稱檸檬)、波斯萊姆 (*Citrus* × *latifolia* 'Persian') (簡稱萊姆) 及茂谷柑 (*Citrus reticulate* × *Citrus sinensis* 'Murcott')，前 2 品種栽培於嘉義縣中埔鄉的有機栽培果園，後者則栽培於嘉義市東區的果園，栽培方式為粗放式管理。調查期間自 2016 年 1−12 月止，每 2 wk 調查 1 次。每品種每次逢機取樣 5 棵植株，每株樹依方位劃分為東、南、西及北方位，每方位逢機選擇 3 顆果實、2 片新葉及 2 片老葉。每一果實與葉片皆取 2 樣本 (2 片膠帶)，果實取樣時避免選擇直射陽光或完全遮陰部位，葉片則正 (葉面)、反 (葉背) 兩面各取 1 樣本。銹蟎在植株各部位調查時期分述如下：果實調查時期為結果期，待果徑寬約 2.5 cm 則開始取樣；新葉則於植株抽新梢時取樣。此外，檸檬與萊姆全年皆有產果，但主要產期仍集中於夏季，故本試驗針對 5−8 月的夏季果實進行調查。試驗園區皆吊掛溫濕度紀錄器 (HOBO® U23 Pro-v2, Onset Computer Corporation)，蒐集園區每日均溫度 (daily temperature) 與相對濕度 (daily relative humidity) 之資料。每日降水量 (daily precipitation) 數據則取自交通部中央氣象局的觀測資料查詢系統 (http://e-service.cwb.gov.tw/HistoryDataQuery/index.jsp)，由於該系統並無提供嘉義縣中埔鄉之數據，故以地理位置相鄰近之番路鄉觀測站資料為參考。

柑橘銹蟎於果園之株內分布狀況

本試驗探討 3 種柑橘植株不同部位之柑橘銹蟎數量差異，分析樣本取自族群動態調查結果。利用適合度檢定 (goodness of fit test) 分別比較柑橘銹蟎於老葉和新葉、葉面與和葉背，及老葉和果實上之數量差異 ($\alpha = 0.05$)。此外，果實上柑橘銹蟎數量之數據經對數轉換 [logarithmic transformation; log (X + 1)]，採用變方分析 (analysis of variance; ANOVA) 比較植株四個方位 (東、南、西及北方位) 果實上柑橘銹蟎數量間的差異，若差異達顯著水準 ($\alpha = 0.05$)，則以 Tukey's honest significant difference (HSD) test 進行事後多重比較 ($\alpha = 0.05$)。試驗數據利用 R project (version 3.2.3) 軟體分析。

柑橘銹蟎於果園之空間分布

三種柑橘品種上柑橘銹蟎之空間分布模式，係以族群動態調查所採集果實、老葉葉面及葉背上銹蟎樣本之平均值 (mean; m) 與變方 (variance; S^2) 兩參數進行分析，若當次調查植株上柑橘銹蟎族群密度為 0，則不進行後續分析。本研究採用 3 種常用之空間分布指數以推測空間分布模式，分別為分散指數 (index of dispersion; ID)、平均擁擠度 (Lloyd's index of mean crowding; m*) 及聚集指數 (Lloyd's index of patchiness; $m^* m^{-1}$) (Lloyd 1967)。分散指數計算公式為 $S^2 m^{-1}$；平均擁擠度指數計算公式為 $m^* = m + S^2 m^{-1}$；聚集指數計算公式則為 $m^* m^{-1}$。三種指數若 < 1、= 1 及 > 1，則分別表示均勻型 (regular)、逢機型 (random) 及聚集型 (contagious) 分布。

結果

柑橘銹蟎於果園之族群動態

柑橘銹蟎族群動態調查為期 1 年，自 2016 年 1 月至同年 12 月，共計調查 26 次。每次於柑橘果實、老葉、新葉所調查之柑橘銹蟎總數及單位面積 (1 cm^2) 平均數量如表 1 所示。於檸檬老葉，葉背上銹蟎密度自 3 月底起逐漸上升，4 月下旬至 5 月上旬達高峰，每平方公分最高密度達 4.2 隻，5 月下旬與 6 月上旬之葉背銹蟎密度則下降為 1.0 與 1.6 隻，此後密度皆幾近於 0.0 隻，直至 11 月底蟎數上升為 2.0 隻。於檸檬葉面上，銹蟎密度較晚於 4 月下旬才上升，5 月上旬達 4.3 隻，而後數量亦大幅下降。於檸檬新葉上，無論葉面或葉背的銹蟎數量皆相當低，整體平均密度於 0.3 隻以下。於檸檬果實上，首次 (5 月 10 日) 調查之銹蟎密度為全年度最高，平均為 30.3 隻，而後銹蟎數量開始下降，自 6 月下旬至 8 月下旬之銹蟎密度極低，僅約 0.1 隻。於萊姆，葉片與果實上的銹蟎密度幾近於 0.0 隻，但果實上仍以

表 1. 柑橘銹蟎於檸檬、萊姆及茂谷柑植株上每平方公分的平均密度。

Table 1. Mean density of rust mites on different parts of lemon, lime, and tangor in 2016.

‘Eureka’ lemon						‘Persian’ lime						‘Murcott’ tangor					
	Old leaf		Young leaf				Old leaf		Young leaf				Old leaf		Young leaf		
Date	Upper surface	Lower surface	Upper surface	Lower surface	Fruit	Date	Upper surface	Lower surface	Upper surface	Lower surface	Fruit	Date	Upper surface	Lower surface	Upper surface	Lower surface	Fruit
Jan-8	-[z]	-				Jan-8	-	-				Jan-7	1.8	6.0			42.2
Jan-19	-	-				Jan-19	-	-				Jan-20	1.7	8.8			20.6
Feb-3	0.0	0.1	-	-		Feb-3	-	-	-	-		Feb-4	0.7	6.8			
Feb-17	-	-	-	-		Feb-17	0.1	-	-	0.0		Feb-17	1.4	8.3			
Mar-1	-	-	-	-		Mar-1	-	-	-	-		Mar-2	1.8	9.4			
Mar-16	-	0.6	0.0	-		Mar-16	-	-	-	-		Mar-17	0.4	10.3			
Mar-29	-	1.3	-	0.2		Mar-29	-	-	-	-		Mar-30	0.1	3.2	0.0	0.2	
Apr-12	0.1	1.1	-	0.2		Apr-12	0.0	-	-	-		Apr-14	-	3.6	0.0	0.1	
Apr-26	2.1	4.2				Apr-26	-	-				Apr-27	0.1	0.9			
May-10	4.3	3.5			30.3	May-10	0.0	0.1			0.1	May-10	-	0.4			
May-24	0.4	1.0			3.2	May-24	-	-			0.0	May-26	0.1	0.1			0.5
Jun-7	0.8	1.6			8.0	Jun-7	0.0	0.0			0.0	Jun-8	0.2	0.1			0.4
Jun-21	-	-	-	-	0.2	Jun-21	-	-	-	-	-	Jun-23	-	0.4			1.4
Jul-5	-	-	-	0.0	0.0	Jul-5	-	-	-	-	0.0	Jul-6	-	-			0.0
Jul-19	-	-	-	-	0.1	Jul-19	-	0.0	-	-	0.0	Jul-20	-	-	-	0.0	-
Aug-2	-	0.1	-	-	0.1	Aug-2	0.0	0.0	-	0.0	0.0	Aug-3	-	-			0.1
Aug-16	-	0.2	-	-	0.1	Aug-16	-	-	-	-	-	Aug-18	-	0.1			1.1
Aug-30	-	-	-	-	0.0	Aug-30	-	-	-	-	0.0	Sep-1	-	-			0.4
Sep-13	-	-	-	-		Sep-13	-	-	-	-		Sep-13	0.1	-			1.2
Sep-26	-	0.1	-	-		Sep-26	-	-	-	-		Sep-26	0.1	0.5			2.9
Oct-11	-	-	-	-		Oct-11	-	-	0.0	0.1		Oct-12	-	0.0			1.2
Oct-24	-	0.1	-	-		Oct-24	0.0	-	-	-		Oct-26	0.1	0.4			7.4
Nov-8	0.1	0.0	-	0.1		Nov-8	0.0	-	0.0	-		Nov-9	0.1	0.2			4.3
Nov-25	0.3	2.0	0.3	1.9		Nov-25	0.0	0.1	0.0	0.1		Nov-22	0.7	1.3			10.1
Dec-6	0.1	0.6				Dec-6	-	0.0				Dec-7	0.2	1.2			5.9
Dec-20	-	0.2				Dec-20	-	-				Dec-22	0.1	0.8			1.3

[z] The dash in each grid means the value was not available, and the space means there were no young leaves or fruits for sampling.

5 月上旬的銹蟎密度最高 (0.1 隻)，而後逐漸降低，其變化趨勢與檸檬果實上略為相似，而葉片上則無明顯趨勢。於茂谷柑老葉上，1–3 月的銹蟎密度為全年度最高，葉面、葉背上的最高密度分別達 1.8 與 10.3 隻，4 月下旬後的銹蟎數量則大幅減少，7–9 月間幾乎無發現銹蟎蹤跡，11 月下旬方略微回升。於茂谷柑新葉上，蟎數皆相當少，最高密度僅 0.2 隻。於茂谷柑果實上，銹蟎密度調查分為兩部分，前半部分 (1 月) 係調查去年 (2015 年) 所結果實，後半部分則自 5 月起，調查對象為本年度所結果實。其中，1 月之柑橘銹蟎密度最高，2 次調查結果分別為 42.2 與 20.6 隻，5–8 月間，茂谷柑果實上的銹蟎密度甚低，平均約0.5 隻，自 9 月起，銹蟎數量方有回升的趨勢，11 月下旬之密度達 10.1 隻。

觀察期間的日均溫、日均相對濕度及每日降水量分別如圖 1、2 所示。氣溫變化上，兩調查地點於 1–3 月之氣溫較低，月均溫為 15.8–18.7℃，其中 1 月 24 日恰逢寒流，為全年度均溫最低日，日均溫僅 5.2–5.5℃；另一方面，氣溫較高月份為 4–10 月，月均溫皆達 25℃以上。全年度的相對溼度變化上，兩地點之日均相對濕度多約為 70–90%，月均相對濕度亦集中於 80–90%。關於降雨量，兩地點全年皆有降雨，但以 5 月下旬至 10 月間的降雨量較高且連續，降雨主要原因除鋒面鋒雨 (梅雨) 與對流雨以外，於 7 月上旬、9 月中旬及下旬侵台之颱風亦皆帶來豐沛雨量 (交通部中央氣象局-颱風資料庫，http://rdc28.cwb.gov.tw/TDB/ntdb/pageControl/ty_warning)。

柑橘銹蟎於果園之株內分布狀況

柑橘銹蟎於 3 種柑橘上全年調查結果，如表 1 所示。於檸檬之老葉、新葉及果實，所調查的柑橘銹蟎累計數量分別為 974、110 及 5,042 隻，於萊姆之老葉、新葉及果實，累計數量分別為 18、13 及 23 隻，於茂谷柑之老葉、新葉及果實，則分別為 2,881、13 及 12,114 隻。由於萊姆上柑橘銹蟎數量過低，全年度總計僅 54 隻，故不進行後續分布狀況之分析。

柑橘銹蟎於檸檬與茂谷柑的老、新葉上之密度差異分析 (圖 3)，調查資料中扣除銹蟎總數皆為 0 的調查點，於檸檬上，老葉之蟎數 (平均密度為每平方公分 0.1–0.6 隻) 顯著多於新葉 (0.0–0.1 隻) 的調查點計有 5 次；老、新葉上蟎數間無顯著差異的調查點則計有 6 次，其中僅 11 月 25 日調查之老、新葉上蟎數皆約為 1.1 隻，其餘調查點之銹蟎密度皆趨於 0.0 隻。於茂谷柑上，老葉之蟎數 (0.5–1.8 隻) 顯

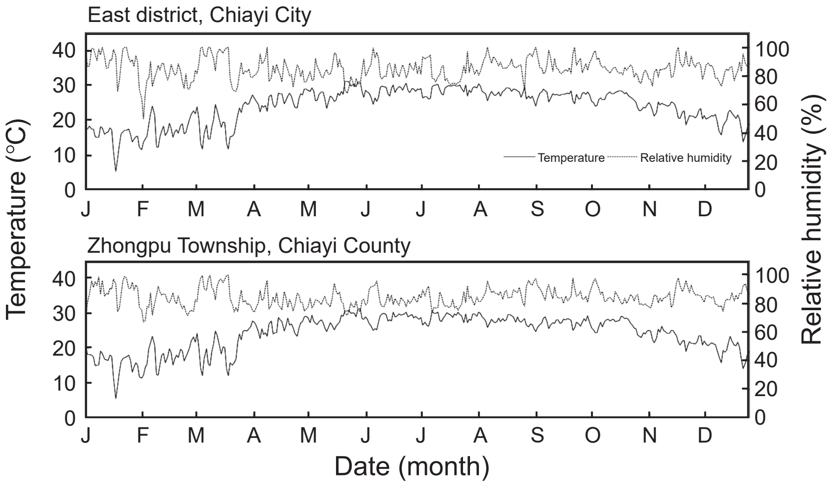


圖 1. 2016 年嘉義市東區與嘉義縣中埔鄉試驗點之日均溫與日均相對濕度變化圖。

Fig. 1. The mean daily temperature and relative humidity at East District, Chiayi City and Zhongpu Township, Chiayi County in 2016.

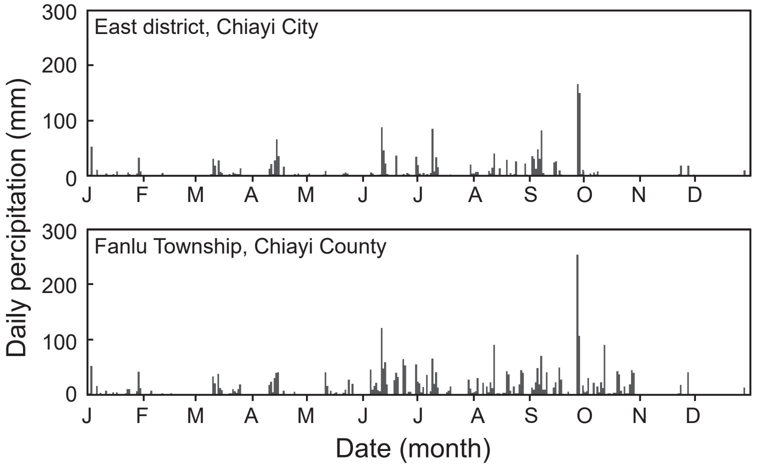


圖 2. 2016 年嘉義市東區與嘉義縣中埔鄉試驗點之每日降水量。

Fig. 2. The daily precipitation at East District, Chiayi City and at Fanlu Township, Chiayi County, in 2016.

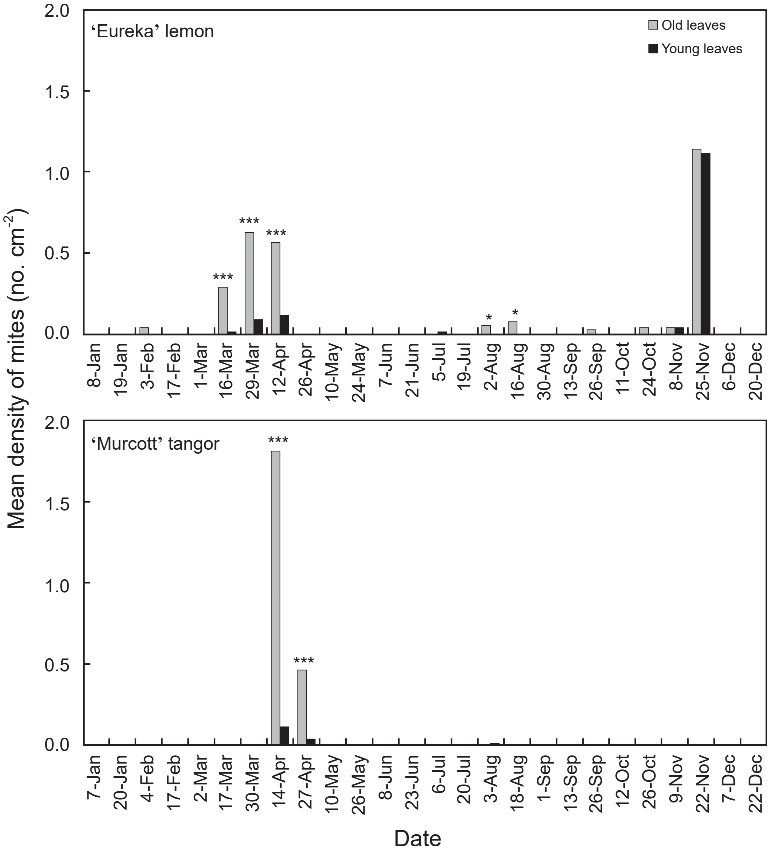


圖 3. 柑橘銹蟎於檸檬與茂谷柑的老、新葉上之密度差異。(僅列舉各部位數據同時皆具之調查點)

Fig. 3. Differences between the mean density of rust mites on old and young leaves, on 'Eureka' lemon and 'Murcott' tangor. (Only the sampling dates with the mites on each part appearing simultaneously were showed.) *,**,***: Bars on the same date with 1, 2 and 3 asterisks are significant different by goodness of fit test at 5, 1 and 0.1%, respectively.

著多於新葉 (0.0−0.1 隻) 的調查點計有 2 次；老、新葉上蟎數間無顯著差異的調查點則計有 1 次。

柑橘銹蟎於檸檬與茂谷柑的老葉葉面、葉背上之密度差異分析 (圖 4)，調查資料中扣除銹蟎總數皆為 0 的調查點，於檸檬上，葉背之蟎數 (0.1−4.2 隻) 顯著多於葉面 (0.0−2.1 隻) 的調查點計有 11 次；葉面、葉背上蟎數間無顯著差異的調查點計有 5 次。於茂谷柑上，葉背之蟎數 (0.4−10.3 隻) 顯著多於葉面 (0.0−1.8 隻) 的調查點計有 16 次；葉面、葉背上蟎數間無顯著差異的調查點則計有 6 次。此外，兩柑橘品種上未達顯著差異之調查點，其葉面、葉背的蟎數相當少，皆未超過 10 隻。

柑橘銹蟎於檸檬與茂谷柑的老葉與果實上之密度差異分析 (圖 5)，調查資料中扣除銹蟎總數皆為 0 的調查點，於檸檬上，果實之蟎數 (0.1−30.3 隻) 顯著多於老葉 (0.0−3.9 隻) 的調查點計有 5 次；果實與老葉上蟎數間無顯著差異的調查點計有 4 次。於茂谷柑上，果實之蟎數 (0.1−42.2 隻) 顯著多於老葉 (0.0−5.3 隻) 的調查點計有 16 次；果實與老葉上蟎數間無顯著差異的調查點則計有 2 次。關於未達顯著差異之調查點，其老葉及果實上的蟎數極少，最多僅 13 隻銹蟎。

柑橘銹蟎於檸檬與茂谷柑的不同方位上之密度差異分析 (表 2)，於檸檬植株上，各次調查中僅 8 月 16 日結果達顯著差異 ($F_{3,112}$ =

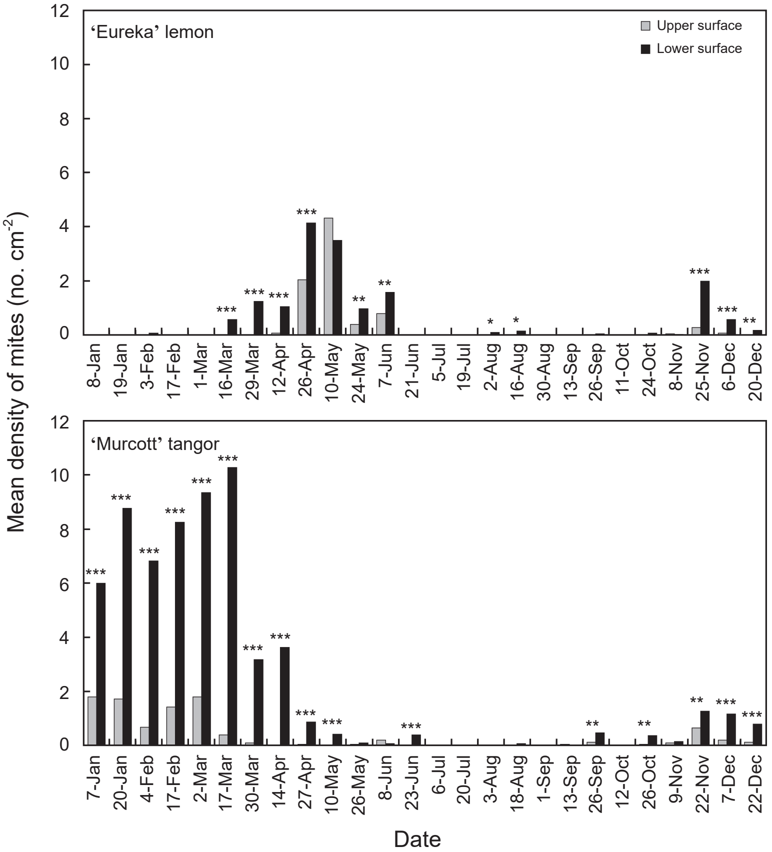


圖 4.　柑橘銹蟎於檸檬與茂谷柑的老葉葉面、葉背上之密度差異。(僅列舉各部位數據同時皆具之調查點)

Fig. 4.　Differences between the mean density of rust mites on upper and lower surfaces of old leaves, on 'Eureka' lemon and 'Murcott' tangor. (Only the sampling dates with the mites on each part of plant appearing simultaneously were showed.) *,**,***: Bars on the same date with 1, 2 and 3 asterisks are significant different by goodness of fit test at 5, 1 and 0.1%, respectively.

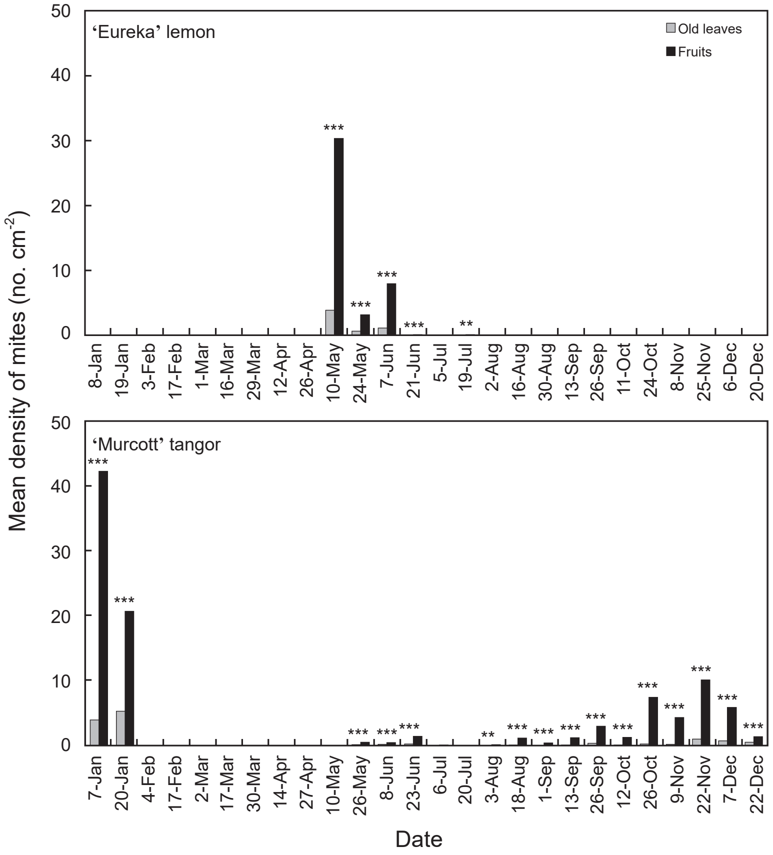


圖 5. 柑橘銹蟎於檸檬與茂谷柑的老葉、果實上之密度差異。(僅列舉各部位數據同時皆具之調查點)

Fig. 5. Differences between the mean density of rust mites on the old leaves and fruits, on 'Eureka' lemon and 'Murcott' tangor. (Only the sampling dates with the mites on each part appearing simultaneously were showed.) *,**,***: Bars on the same date with 1, 2 and 3 asterisks are significant different by goodness of fit test at 5, 1 and 0.1%, respectively.

表 2 柑橘銹蟎於柑橘植株不同方位之平均密度。

Table 2. Mean density of rust mites in 1 cm^2 area in different directions of the tree.

	Mean density of mites (No. mites cm^{-2})			
Fruiting period[z]	North	East	South	West
Lemon				
Aug-16	0.2 a[y]	0.1 b	0.0 b	0.2 a
'Murcott'				
Jan-7	75.9 a	26.9 ab	11.2 b	54.8 a
Jan-20	40.3 a	17.4 a	3.7 b	21.1 ab
Sep-1	0.3 ab	0.8 a	0.3 ab	0.1 b
Oct-26	16.2 a	5.1 b	2.1 b	6.2 ab
Dec-7	5.1 b	9.3 a	6.4 b	2.6 b

[z] Only the values of dates with significant difference in directions were showed.
[y] Values within a row followed by the same letter are not significantly different at the 5% level of probability ($P < 0.05$).

0.023, $P < 0.05$)，以北方與西方密度較高，平均密度皆約為 0.2 隻，南方則為四方位中最低 (蟎數為 0 隻)。於茂谷柑植株上，各次調查結果中有 5 次調查點達顯著差異，分別為 1 月 7 日 ($F_{3,112} = 6.021$, $P < 0.001$)、1 月 20 日 ($F_{3,112} = 6.343$, $P < 0.001$)、9 月 1 日 ($F_{3,112} = 3.813$, $P < 0.05$)、10 月 26 日 ($F_{3,112} = 6.113$, $P < 0.001$) 及 12 月 7 日 ($F_{3,112} = 2.943$, $P < 0.0.5$)。其中，南方密度顯著低於其他方位之調查點計有 4 次，僅 1 次調查結果顯示與其他方位間無顯著差異。

柑橘銹蟎於果園之空間分布

柑橘銹蟎於 3 種柑橘品種上之分散指數、平均擁擠度及聚集指數，分別如圖 6–8 所示。扣除銹蟎總數皆為 0 的調查點，於檸檬與茂谷柑上，當柑橘銹蟎平均密度 > 0.1 隻，3 種空間分布指數亦多呈聚集型分布，而當平均密度 < 或 = 0.1 隻，3 種空間分布指數則轉為呈現均勻型或逢機型分布。於萊姆上，三種空間分布指數多為 = 1，以逢機型分布為主。整體而言，於檸檬與茂谷柑的果實、老葉 (葉面與葉背) 上，柑橘銹蟎多呈聚集型分布，惟密度極低時 (< 或 = 0.1 隻)，則可能呈現均勻型或逢機型分布。於萊姆植株的果實與葉片上，全年的柑橘銹蟎密度皆相當低 (< 0.1 隻)，且族群多為逢機型分布。

討論

本研究於檸檬的調查結果與多數報告相似，柑橘銹蟎族群以春、夏為高峰。另一方面，由於茂谷柑於台灣的果期較早 (1–2 月採收)，有別於其他文獻的柑橘種類，故柑橘銹蟎集中於結果期的秋、冬季發生，而與檸檬及往昔文獻所載於其他柑橘品種上之發生高峰期不同 (表 1)。在世界柑橘類產區，柑橘銹蟎於全年的族群動態變化上，多以較溫暖的春、夏兩季為密度高峰期，但因氣候環境及寄主品種的差異，族群變化上仍有些許不同。如於佛羅里達州之晚崙西亞橙果園，發現，柑橘銹蟎在

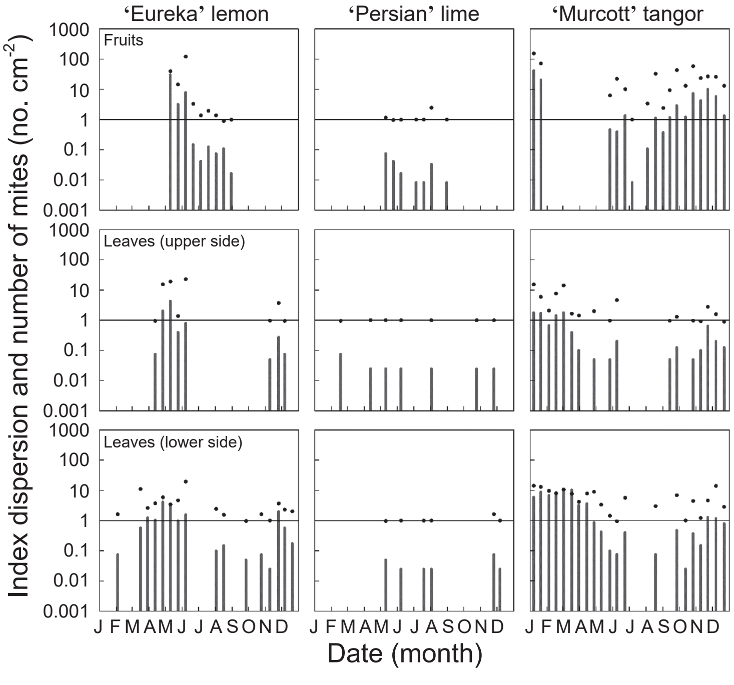


圖 6. 柑橘銹蟎於 3 種柑橘植株上之分散指數 (黑色圓圈) 與族群密度 (灰色直條)。

Fig. 6. The indices of dispersion (solid circle) and population density (grey bar) of the citrus rust mites on three varieties of citrus plants.

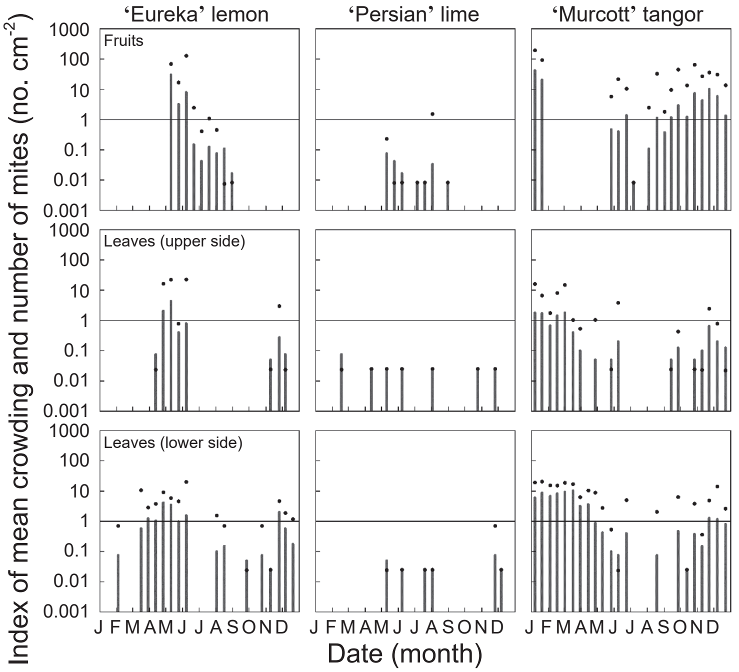


圖 7. 柑橘銹蟎於 3 種柑橘植株上之平均擁擠度 (黑色圓圈) 與族群密度 (灰色直條)。

Fig. 7. The indices of mean crowding (solid circle) and population density (grey bar) of the citrus rust mites on three varieties of citrus plants.

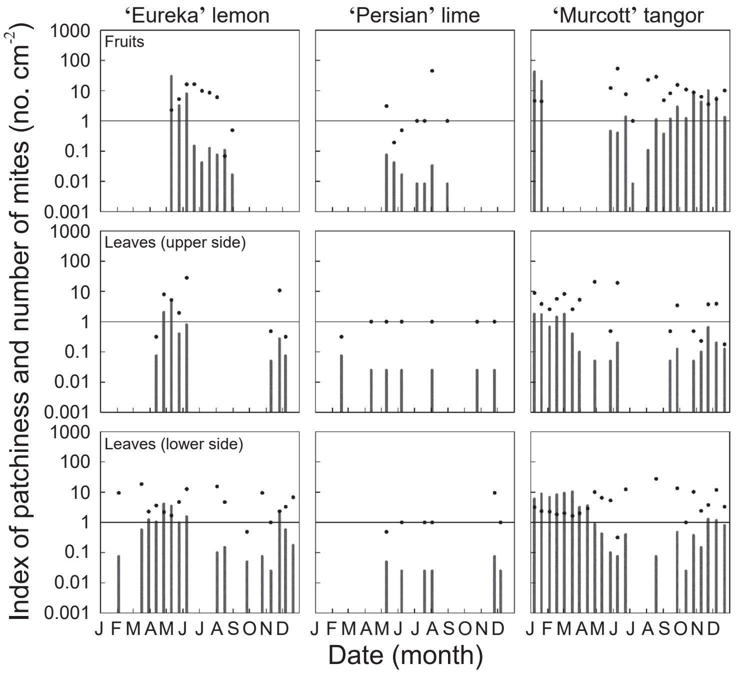


圖 8. 柑橘銹蟎於 3 種柑橘植株上之聚集指數 (黑色圓圈) 與族群密度 (灰色直條)。

Fig. 8. The indices of patchiness (solid circle) and population density (grey bar) of the citrus rust mites on three varieties of citrus plants.

葉片與果實上的族群數量，自 5 月起迅速攀升，7–8 月達最高峰，8 月下旬後則又快速下降 (Albrigo & McCoy 1974)。相同地，於埃及的布海拉 (Buhaira) 省，華盛頓臍橙 (Washington Navel orange) 植株上的柑橘銹蟎族群，亦約在 6–9 月達發生盛期，平均每葉、果上最高紀錄分別達 49 與 71 隻柑橘銹蟎 (Al-Azzazy 2016)。然而，位於緯度更低的地區，例如哥斯大黎加的阿拉胡埃拉省，晚崙西亞橙上的柑橘銹蟎密度卻以 2 月、3 月及 5 月為高峰期，而造成其餘月份族群數量較低的原因，應與環境相對濕度及降雨有所關聯 (González *et al*. 1985)。在蘇利南，柑橘銹蟎於葡萄柚上，則集中於非雨季的 9–11 月及 2–3 月發生 (Van Brussel 1975)。

自 5 月下旬後，本研究結果顯示檸檬上的柑橘銹蟎族群數量不如預期增加，反之銳減，甚至趨近於零，於茂谷柑上亦有蟎數密度較低的類似趨勢。調查期間，於 5–8 月 (檸檬結果期) 的氣溫與相對濕度皆相當穩定，日均溫普遍超過 25℃，日均相對濕度則多為 70–90% (圖 1)。但降雨量上，5 月下旬至 10 月的降雨量較高且密集，中埔鄰近地區以 6–10 月的日均降水量逾 20 mm 之日數則計有 54 d，嘉義市雨量則較少，但仍有 30 d 的日均降水量逾 20 mm (圖 2)。事實上，環境溫度、相對濕度及降雨等因素，皆會影響柑橘銹蟎發生。有關溫度對柑橘銹蟎的發育與族群動態之研究，柑橘銹蟎最適發育溫度為 30–32℃，11.07℃則為發育臨界低溫 (Allen *et al*. 1995; Ebrahim 2000)，而於 23–32℃的環境溫度下，銹蟎自卵發育至成蟎所需有效積溫為 330.07 degree-days (Vacante 2009)。此外，隨著環境溫度降低，銹蟎的死亡率亦有提高的趨勢，於 17℃下的銹蟎死亡率高達 53.06% (Ebrahim 2000)。因此，銹蟎於溫暖的環境下發育快速，低溫則有礙銹蟎生長發育，亦可能造成田間族群高峰期推遲 (Yothers & Mason 1930)。相對濕度對於銹蟎發生動態之研究指出，濕度較高的環境有助於柑橘銹蟎生長，過於乾燥反而不利 (Pratt 1957; Dean 1959; Reed *et al*. 1964)。有關降雨對柑橘銹蟎族群的影響，Yothers & Mason (1930) 認為，雨水僅能將植株上少部分的銹蟎刷落，雨後適合寄生蟎類的蟲生真菌發生之潮濕環境，才為銹蟎族群減少的主因。Van Brussel (1975) 則指出，降雨對柑橘銹蟎發育具直接性地負面影響，會造成若蟎死亡率增加、影響產卵行為。基於往昔文獻與本研究結果，中埔地區的溫度與相對濕度，應相當適合銹蟎生長。反之，由於當年度的雨量豐沛且密集，降雨量遠超過上述文獻之紀錄，又因所調查之檸檬、茂谷柑樹齡僅 3–5 年，供柑橘銹蟎遮蔽的樹冠有限，連續大雨應足以沖刷掉植株上多數的銹蟎。因此，推測於春、夏季的連續降雨，為本次調查的柑橘植株上銹蟎族群數量銳減主因之一。

柑橘銹蟎於 3 種柑橘之分布上，不同部位的銹蟎密度以果實最高，老葉次之，新葉上往往最低，且普遍以葉背的蟎數顯著多於葉面 (圖 3、4、5)。事實上，不少往昔研究於不同柑橘品種上，亦觀察到果實上柑橘銹蟎密度較葉片高 (Yothers & Mason 1930; Albrigo & McCoy 1974; Aghajanzadeh & Mallik 2007; Vacante 2009)、葉背蟎數多於葉面之現象 (Yothers & Mason 1930; Vacante 2009)。而據 McCoy (1979) 觀察，柑橘銹蟎於春季 (3 月下旬)，會由舊梢往新梢之葉背或嫩枝條移動，且族群於新梢上的增殖率與數量較高。相較之下，本研究於 3 種柑橘植株上，並無觀察到新梢蟎數較多的情形，僅檸檬春稍期的新葉上蟎數呈逐漸增加之趨勢。如前段所推測，由於嘉義地區於當年度的雨水豐沛，造成葉片上蟎數於 5 月下旬後即迅速減少，柑橘銹蟎難以於新葉上建立大量族群，故於新、老葉上的發生狀況與 McCoy (1979) 的報告不同。

柑橘銹蟎於柑橘不同方位上的分布，顯示銹蟎無偏好於特定方位，僅少數呈現方位上之差異，其中多又以南方的密度較低 (表 2)。事實上，許多研究報告於此方面的研究結果不盡相同，例如，於印度的苦橙 (*Citrus* × *aurantium*) 與甜萊姆 (*Citrus limetta*, mosambi fruit) 果園，Aghajanzadeh & Mallik (2007) 觀察到植株東方蟎數最多，而 Van Brussel (1975) 於蘇利南卻發現東方最少。由於陽光為影響柑橘銹蟎分布的因素之一，而受日照程度較高之

方位的蟎數往往較少 (Yothers & Mason 1930; Albrigo & McCoy 1974; Van Brussel 1975; Allen & McCoy 1979; Vacante 2009)。又因世界各地區之地理環境不同，日照、風向等因子皆異，故而各地調查結果不一。以位於北半球的台灣而言，植株南方受日照時間較長，此或許係南方柑橘銹蟎偶有數量較少的原因之一。

有關柑橘銹蟎於植株上的空間分布型態，於漢林橙 ('Hamlin' orange) 與晚崙西亞橙，銹蟎族群一般多呈現聚集型分布，惟密度過低時例外 (Hall *et al*. 1994)，Peña & Baranowski (1990) 於墨西哥萊姆，亦觀察到相似結果。除柑橘銹蟎以外，其他種類之節蟎，甚至不同科的蟎類，如葉蟎、細蟎等，亦常以聚集型態棲息於田間 (Peña & Baranowski 1990; Zhang & Sanderson 1995; Li & Chen 2015)。相同地，本研究結果顯示，柑橘銹蟎於檸檬、茂谷柑上，族群普遍呈現聚集型分布，惟族群數量降至極低 (= 或 < 0.1 隻)，則可能出現均勻型或逢機型分布 (圖 6、7、8)。此外，儘管 6−10 月間降雨頻繁，檸檬、茂谷柑上蟎數較少，但銹蟎族群仍多呈現聚集型分布。由於柑橘銹蟎係借靠風力於不同植株間移動移動 (Bergh & McCoy 1997; Bergh 2001)，且能行孤雌生殖繁衍子代 (Vacante 2009)。因此，大雨雖造成族群數量下降，但倘若環境合適，銹蟎仍能隨風飄散至周遭寄主並建立族群，故仍呈聚集型分布。反之，儘管於萊姆上的柑橘銹蟎數量亦相當低，卻少有呈現聚集型分布，故推測銹蟎難以於萊姆植株上正常生存或繁衍後代。

全年於萊姆所採集的柑橘銹蟎總數僅有 54 隻，遠少於檸檬與茂谷柑上之數量。本研究所調查之萊姆、檸檬果園相鄰，兩品種果期相近，且萊姆園內亦交錯栽種不少檸檬植株，兩園區之地理環境及柑橘銹蟎感染機率應雷同，然而兩品種間的柑橘銹蟎數量卻差異甚大。Huang (1966) 曾於台灣之波斯萊姆上採集到柑橘銹蟎，故將波斯萊姆視為寄主植物，惟該文獻並無記載所採集之銹蟎數量。與波斯萊姆不同，不少報告於墨西哥萊姆或甜萊姆上皆觀察到為數不少的柑橘銹蟎 (Yothers & Mason 1930; Peña & Baranowski 1990; Aghajanzadeh & Mallik 2007)。另一方面，Yothers & Mason (1930) 調查柑橘銹蟎對不同品種柑橘 (或雜交種) 及其他芸香科植物之偏好性，其中柑橘屬與金柑屬植物上皆有發現柑橘銹蟎，但於數量上卻有所差異，顯示銹蟎對不同柑橘品種的偏好程度不一，例如 *Citrus faustrime* 上的蟎數即相當少，其報告在近 3 年的調查中，有 2 年幾乎沒發現銹蟎蹤跡。因此，或許寄主偏好性差異之故，以至於銹蟎不易於波斯萊姆上繁衍後代，而本研究亦將持續相關試驗以驗證此推測。

台灣四季普遍溫暖、多濕，適宜柑橘銹蟎發生，而透過本研究結果與往昔文獻可得知，柑橘銹蟎族群動態與環境溫度、濕度、日照等地理環境之關係密不可分，各地區影響銹蟎之主因亦不相同 (Vacante 2009)。本研究結果亦顯示，檸檬與茂谷柑之結果期為銹蟎好發的時間點，小果期即可發現其蹤跡。植株不同部位中，以果實上銹蟎數量最多，其次為老葉，葉背蟎數亦較葉面多。此外，連續且頻繁之降雨，會導致銹蟎族群數量減少，但銹蟎仍能於環境適合時重新建立族群。因此，於柑橘銹蟎好發的檸檬、茂谷柑果園，建議於小果期前即開始防治，且針對銹蟎密度可能較高的果實與葉背加強施藥，應該達到較佳的族群抑制效果。儘管如此，因近幾年來的極端氣候事件愈趨頻繁，全年乾旱或暴雨之情況時有發生，已難就單年度調查結果推論往後之族群動態。是故，本研究將持續進行，以便獲得更多柑橘銹蟎之相關資訊，藉此評估銹蟎族群於不同氣候下的發生狀況。

誌謝

本研究承蒙廖治榮先生協助蟎類鑑定，及嘉義農業試驗分所研究室同仁朱宜芬小姐、周紹宸先生協助試驗進行，謹此致謝。

引用文獻

Achor, D. S., L. G. Albrigo, and C. W. McCoy. 1991. Developmental anatomy of lesions on 'Sunburst' mandarin leaves initiated by citrus rust mite feeding. J. Amer. Soc. Hort. Sci. 116:663–668.

Aghajanzadeh, S. and B. Mallik. 2007. Sampling and distribution pattern of citrus rust mite, *Phyllocoptruta oleivora* Ashmead (Acari, Eriophyidae) using adhesive tape method. Intl. J. Agric. Biol. 9:329–332.

Al-Azzazy, M. M. 2016. Population fluctuation and control of the citrus rust mite, *Phyllocoptruta olievora* (Ashmead) (Arachnida: Prostigmata: Eriophyidae). J. Agric. Vet. Sci. 9:175–186.

Albrigo, L. G. and C. W. McCoy. 1974. Characteristic injury by citrus rust mite to orange leaves and fruit. Proc. Fla. State Hort. Soc. 87:48–55.

Allen, J. C. 1978. The effect of citrus rust mite damage on citrus fruit drop. J. Econ. Entomol. 71:746–750.

Allen, J. C. 1979a. Effect of citrus rust mite damage on citrus fruit growth. J. Econ. Entomol. 72:195–201.

Allen, J. C. 1979b. The effect of citrus rust mite damage on fruit drop in three citrus varieties. Proc. Fla. State Hort. Soc. 92:46–48.

Allen, J. C. and C. W. McCoy. 1979. The thermal environment of the citrus rust mite. Agric. Meteorol. 20:411–425.

Allen, J. C., Y. Yang, and J. L. Knapp. 1995. Temperature effects on development and fecundity of the citrus rust mite (Acari: Eriophyidae). Environ. Entomol. 24:996–1004.

Bergh, J. C. 2001. Ecology and aerobiology of dispersing citrus rust mites (Acari: Eriophyidae) in central Florida. Environ. Entomol. 30:318–326.

Bergh, J. C. and C. W. McCoy. 1997. Aerial dispersal of citrus rust mite (Acari: Eriophyidae) from Florida citrus groves. Environ. Entomol. 26:256–264.

Dean, H. A. 1959. Seasonal distribution of mites on Texas grapefruit. J. Econ. Entomol. 52:228–232.

Ebrahim, H. M. 2000. Influence of temperature and relative humidity on the biology and life table parameters of *Phyllocoptruta oleivora* and *Aculops pelekassi* (Acari: Eriophyidae) on 'Hamlin' orange in Central Florida. Egypt. J. Agric. Res. 78:143–161.

González, M., L. A. Salas, and R. L. Hernández. 1985. Biotic and abiotic factors influencing the population densities of *Phyllocoptruta oleivora* (Acari: Eriophyidae) in orange. Agron. Costarric. 9:205−211. (in Spanish with English abstract)

Griffiths, J. T. and W. L. Thompson. 1957. Insects and Mites Found in Florida Citrus. Univ. Fla. Agric. Exp. Sta. Bull. No. 591. Agricultural Experiment Stations, University of Florida. Gainesville, FL. 96 pp.

Hall, D. G., C. C. Childers, and J. E. Eger. 1994. Spatial dispersion and sampling of citrus rust mite (Acari: Eriophyidae) on fruit in 'Hamlin' and 'Valencia' orange groves in Florida. J. Econ. Entomol. 87:687–698.

Huang, T. 1966. Eriophyid mites of citrus trees in Taiwan (I). Plant Prot. Bull. 8:391–400. (in Chinese with English abstract)

Li, C. Y. and W. H. Chen. 2015. Spatial distribution, estimates of optimal sample size and population dynamics for *Oligonychus litchii* Lo et Ho (Acari: Tetranychidae) on wax apple. Formosan Entomol. 35:117–133.

Lindquist, E. E., M. W. Sabelis, and J. Bruin. 1996. Eriophyoid Mites: Their Biology, Natural Enemies and Control. Elsevier Science. Amsterdam, the Netherlands. 822 pp.

Lloyd, M. 1967. Mean crowding. J. Anim. Ecol. 36:1–30.

Lo, K. C. 2006. Illustration of Mite Pests on Agricultural Crops in Taiwan. Taiwan Agricultural Research Institute. Taichung, Taiwan. 216 pp. (in Chinese)

McCoy, C. W. 1976. Leaf injury and defoliation caused by the citrus rust mite, *Phyllocoptruta oleivora*. Fla. Entomol. 59:403–410.

McCoy, C. W. 1979. Migration and development of citrus rust mite on the spring flush of Valencia orange. Proc. Fla. State Hort. Soc. 92:48–51.

McCoy, C. W. and L. G. Albrigo. 1975. Feeding injury to the orange caused by the citrus rust mite, *Phyllocoptruta oleivora* (Prostigmata: Eriophyoidea). Ann. Entomol. Soc. Amer. 68:289–297.

McCoy, C. W., P. L. Davis, and K. A. Munroe. 1976. Effect of late season fruit injury by the citrus rust mite, *Phyllocoptruta oleivora* (Prostigmata: Eriophyoidea), on the internal quality of Valencia orange. Fla. Entomol. 59:335–341.

Peña, J. E. and R. M. Baranowski. 1990. Dispersion indices and sampling plans for the broad mite (Acari: Tarsonemidae) and the citrus rust mite (Acari: Eriophyidae) on limes. Environ. Entomol. 19:378–382.

Pratt, R. M. 1957. Relation between moisture conditions and rust mite infestations. Proc. Fla. State Hort. Soc. 70:48–51.

Reed, D. K., D. K. Burditt, and C. R. Crittenden. 1964. Laboratory methods for rearing rust mites (*Phyllocoptruta oleivora* and *Aculus pelekassi*) on citrus. J. Econ. Entomol. 57:130–133.

Rogers, M. E. and P. A. Stansly. 2016. Rust mites, spider mites, and other phytophagous mites. p.39−43. *in*: 2016 Florida Citrus Pest Management Guide (Rogers, M. E. and M. M. Dewdney, eds.) IFAS Extension, University of Florida. Lake Alfred, FL. 128 pp.

Vacante, V. 2009. Citrus Mites: Identification, Bionomy and Control. Centre for Agriculture and Bioscience International. Oxfordshire, UK. 378 pp.

Van Brussel, E. W. 1975. Interrelations between citrus rust mite, *Hirsutella thompsonii* and greasy spot on citrus in Surinam. Bull. Agric. Exp. Stat. Surinam 98:1–66.

Winston, J. R. 1920. Tear stain of Florida citrus fruits, its cause and control. Proc. Fla. State Hort. Soc. 33:122–127.

Yang, Y., J. C. Allen, J. L. Knapp, and P. A. Stansly. 1994. Citrus rust mite (Acari: Eriophyidae) damage effects on 'Hamlin' orange fruit growth and drop. Environ. Entomol. 23:244–247.

Yothers, W. W. and A. C. Mason. 1930. The citrus rust mite and control. USDA Tech. Bull. 176:7–16.

Zhang, Z. Q. and J. P. Sanderson. 1995. Twospotted spider mites (Acari: Tetranychidae) and *Phytoseiulus persimilis* (Acari: Phytoseiidae) on greenhouse roses: Spatial distribution and predator efficacy. J. Econ. Entomol. 88:352–357.

Population Dynamic and Spatial Distribution of the Citrus Rust Mite, *Phyllocoptruta oleivora* (Ashmead), on Three Varieties of Citrus in Taiwan

Po-Hung Chen[1], Tai-Chuan Wang[1], Chi-Nan Chen[2], Chiung-Hui Huang[3], and Shou-Horng Huang[4,*]

Abstract

Chen, P. H., T. C. Wang, C. N. Chen, C. H. Huang, and S. H. Huang. 2018. Population dynamic and spatial distribution of the citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), on three varieties of citrus in Taiwan. J. Taiwan Agric. Res. 67(2):166–180.

The citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), is a major pest of citrus plants in Taiwan. Citrus rust mites feed on leaves and fruit surfaces, significantly affecting the quality of citrus products. The present study investigated the field population dynamics and spatial distribution of citrus rust mites on 'Eureka' lemons, 'Persian' limes, and 'Murcott' tangors from January to December in 2016. Study results regarding the three varieties of citrus plants showed that citrus rust mite populations reached the highest density during fruit growing periods. Fruits suffered the highest density of mite infestations and followed by mature leaves, and young leaves suffered the least damage. The number of citrus rust mites on the lower surface of leaves were higher than that on the upper surface of leaves. The direction of fruits growing on citrus plants did not significantly affect the number of citrus rust mites population. Rainfall and precipitation frequency may be one of the key factors causing low density of mites from May to October. Three indices (index of dispersion, Lloyd's index of mean crowding and Lloyd's index of patchiness) used to identify the spatial distribution pattern of citrus rust mites all indicated contagious patterns of spatial distribution except when mite density was very low, the distribution patterns became regular or random.

Key words: Citrus rust mite, Population dynamic, Spatial distribution.

Received: July 25, 2017; Accepted: September 19, 2017.

* Corresponding author, e-mail: shhuang@dns.caes.gov.tw

1 Assistant Research Fellows, Department of Plant Protection, Chiayi Agricultural Experiment Branch, Taiwan Agricultural Research Institute, Chiayi, Taiwan, ROC.

2 Assistant Research Fellow, Department of Horticulture, Chiayi Agricultural Experiment Branch, Taiwan Agricultural Research Institute, Chiayi, Taiwan, ROC.

3 Research Assistant, Department of Plant Protection, Chiayi Agricultural Experiment Branch, Taiwan Agricultural Research Institute, Chiayi, Taiwan, ROC.

4 Associate Research Fellow, Department of Plant Protection, Chiayi Agricultural Experiment Branch, Taiwan Agricultural Research Institute, Chiayi, Taiwan, ROC.

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):181–190 (2018)
DOI: 10.6156/JTAR.201806_67(2).0004

研究報告

溫度依變下小黃薊馬 (*Scirtothrips dorsalis* Hood) 在檬果上之發育及生命表

賴信順 [1]　陳怡如 [2]　邱一中 [3]　林鳳琪 [4,*]

摘要

賴信順、陳怡如、邱一中、林鳳琪。2018。溫度依變下小黃薊馬 (*Scirtothrips dorsalis* Hood) 在檬果上之發育及生命表。台灣農業研究 67(2):181–190。

小黃薊馬 (*Scirtothrips dorsalis* Hood) 以檬果 (*Mangifera indica* L.) 葉片飼養於 16、20、24、28、32、34 與 36℃定溫下，觀察溫度對其各齡期發育時間的影響，並以兩性生命表分析其在 20、24、28、32 與 34℃的族群介量。結果顯示，各蟲期在 16–36℃時平均發育時間分別卵期為 4.1–19.1 d，一齡幼蟲期為 1.4–5.7 d，二齡幼蟲期為 1.3–8.2 d，蛹期為 1.5–7.9 d，由卵發育至成蟲為 8.5–42.0 d。由直線迴歸分析卵發育至成蟲的發育總積溫為 206.14 日度 (degree-days)，發育臨界低溫為 10.7℃。另由非線性迴歸分析發育臨界低溫為 10.6℃，最適發育溫度為 35.6℃。以兩性生命表分析結果，其內在增殖率 (r_m) 與終極增殖率 (λ) 皆以 28℃時為最大 (r_m = 0.2009 d^{-1}、λ = 1.2226 d^{-1})，20℃時為最小 (r_m = 0.0824 d^{-1}、λ = 1.0859 d^{-1})。淨增殖率 (R_0) 也是以 28℃為最大 (R_0 = 40.82 子代/代)，但 34℃時為最小 (R_0 = 4.14 子代/代)。平均世代時間 (T) 以 20℃時為最長 (T = 32.77 d)，34℃時為最短 (T = 12.15 d)。

關鍵詞：小黃薊馬、檬果、溫度、發育速率、生命表。

前言

檬果 (*Mangifera indica* L.) 原產於印度，屬於漆樹科 (Anacardiaceae) 的熱帶果樹。在台灣的產區集中於台南市、高雄市與屏東縣等地區，因品種特性不同，所以生產期可從 3–10 月 (Chiou & Lee 2012)。前人調查紀錄台灣檬果上的害蟲 (蟎) 種類共有 6 目 27 科 80 種害蟲及 1 目 2 科 6 種害蟎，其中薊馬有 6 種，主要薊馬種類是小黃薊馬 (*Scirtothrips dorsalis* Hood) (Wei *et al*. 2011; Shih *et al*. 2013)。小黃薊馬從檬果抽梢期經開花期到小果期都可見其危害，為嚴重影響台灣檬果品質的重要害蟲之一 (Wen & Wu 2010)，並且在馬來西亞與印尼等世界檬果主要產地亦是檬果的重要害蟲 (Aliakbarpour *et al*. 2010; Affandi & Medina 2013)。

小黃薊馬屬於纓翅目薊馬科 (Thysanoptera: Thripidae)，為容易造成經濟損失的入侵種薊馬之一，寄主植物超過 40 科 100 種以上，為高度雜食性的昆蟲 (Morse & Hoddle 2006)。小黃薊馬對作物的危害可分為直接刺吸取食造成危害，與媒介病毒病 *Tospovirus* 所造成的間接危害 (Kumar *et al*. 2013)。小黃薊馬對檬果所造成的危害屬於直接危害，包括吸食嫩稍、嫩芽、嫩葉與幼葉的汁液後，導致發育不良甚至變形枯萎；吸食花穗造成不利花器發育；吸食幼果表皮的食痕，則隨著果實發育

投稿日期：2017 年 7 月 24 日；接受日期：2017 年 9 月 30 日。
[*] 通訊作者：fclin@tari.gov.tw
[1] 農委會農業試驗所鳳山熱帶園藝試驗分所植物保護系助理研究員。台灣 高雄市。
[2] 農委會農業試驗所應用動物組助理研究員。台灣 台中市。
[3] 農委會農業試驗所應用動物組聘用助理研究員。台灣 台中市。
[4] 農委會農業試驗所應用動物組副研究員。台灣 台中市。

而形成明顯褐化結痂，嚴重影響鮮果販賣的商品價值 (Lin *et al*. 2010; Shih *et al*. 2013)。

溫度對生物的影響範圍從生理生化層級到個體、族群、群落甚至到生態系統層級，而昆蟲屬於變溫性動物，所以溫度對於昆蟲的影響更為明顯 (Colinet *et al*. 2015)。為探討溫度與昆蟲發育速率之間的關係，因此發展了各種不同的直線或是非線性迴歸分析，以推測昆蟲的發育臨界低溫 (low temperature threshold)、發育臨界高溫 (high temperature threshold)、最適發育溫度 (optimal temperature) 或有效積溫 (thermal summation) 等資訊 (Quinn 2017)。在評估溫度對昆蟲族群動態的影響時，通常是藉由生命表分析來估算不同溫度時昆蟲的族群介量 (population parameter)。

本研究以檬果葉片作為小黃薊馬的生活棲所，在不同恆溫下觀察小黃薊馬的生長與發育情形，部分數據已於 2013 年發表 (Chen *et al*. 2013)。而本報告除新增試驗項目及內容外，並且以直線與非線性迴歸分析加強說明溫度與小黃薊馬發育速率之間的關係，同時利用兩性生命表分析來估算不同恆溫下小黃薊馬的族群介量，希望能提供防治上參考。

材料與方法

供試昆蟲

將採集自台南市玉井區的檬果園內的小黃薊馬，接蟲於農委會農業試驗所實驗室內栽種之檬果幼葉飼養繁殖，作為試驗用蟲源。

試驗載台

試驗載台為在平底玻璃管 (diam. 3.0 cm) 內，於管底放置圓形濕潤紙片 (diam. 2.8 cm)，並於其上放置被裁切為圓形的新鮮檬果葉片 (diam. 2.8 cm)。

不同恆溫下各齡期發育與成蟲產卵觀察

由供試蟲源挑選小黃薊馬雌成蟲置於有檬果葉片的試驗載台內，以石蠟膜封住管口，並在膜上戳洞以減少水分的凝結。將玻璃管分別置於 16、20、24、28、32、34 與 36℃等 7 種恆溫，相對濕度為 80%，相對濕度及光週期 12 L：12 D的梯度生長箱中，任其產卵24 h後，移除所有成蟲。每日定時觀察卵孵化情形，待孵化為一齡幼蟲後，用毛筆將幼蟲分別挑至有檬果葉片的試驗載台內單隻飼養，每日定時觀察紀錄小黃薊馬之發育情形。

將 20、24、28、32、34 與 36℃下所發育之成蟲個體，分別經雌雄配對置於有檬果葉片的試驗載台後，每日定時取出葉片，於解剖顯微鏡下觀察計算產卵數，並更換新鮮檬果葉片供其產卵，直至成蟲死亡為止。

不同溫度與各蟲期發育速率迴歸分析

選擇直線及 Lactin-2 非線性之迴歸分析，探討溫度與小黃薊馬發育速率兩者之關係，其中發育速率 (D) 為發育所需時間之倒數。

直線迴歸模式 (Campbell *et al*. 1974)，定義為：

$$\mathrm{D}(T) = a + bT$$

其中 T 為飼養定溫 (℃)，a 為溫度等於 0℃時的發育速率，b 為該直線迴歸方程式中的斜率。由估算所得迴歸方程式，計算發育總積溫 (K = 1/b) 及並以外插法估算其發育臨界低溫 (T_0 = -a/b)。其中發育總積溫 (K) 的標準誤差 (standard error; S.E.) 由下列公式計算：

$$\frac{\mathrm{S.E.\ of\ } b}{b^2}$$

及發育臨界低溫 (T_0) 的標準誤差則以下列公式計算：

$$\frac{\bar{y}}{b}\sqrt{\frac{S^2}{N\bar{y}^2}+\left[\frac{\mathrm{S.E.\ of\ } b}{b}\right]^2}$$

其中 $\bar{y}$ 是樣本平均，N 是樣本數量，S^2 是樣本的殘差平均平方和 (residual mean square)。

Lactin-2 非線性迴歸分析 (Lactin *et al*. 1995)，定義為：

$$\mathrm{D}(T) = e^{\rho T} - e^{\rho T_L - \frac{T_L - T}{\Delta T}} + \lambda$$

其中 T 是飼養的溫度 (℃)，T_L 是致死高溫 (lethal maximum temperature)，ΔT 為最適發育溫度 (即為發育速率最大時的溫度) 與致死高溫間之差值，ρ 和 λ 是估算介量。藉此非線性迴歸分析估算 $D(T) = 0$ 發育臨界低溫與臨界高溫以及 $dD(T)/dT = 0$ 時的最適發育溫度。

溫度對發育速率直線迴歸與非線性迴歸分析均利用 SPSS 統計軟體運算 (SPSS 10.0 for Windows; SPSS Inc.)，圖則以 Sigmaplot 軟體繪製 (Systat Software Inc.)。

不同溫度下生命表及族群介量分析

依 Chi (1988) 之兩性生命表理論，將不同恆溫下飼養小黃薊馬之生活史資料，利用TWO-SEX-MSChart 軟體 (http://140.120.197.173/Ecology/Download/Twosex-MSChart-exe-B100000.rar) (Chi 2013) 計算出小黃薊馬在 20、24、28、32 與 34℃下之齡別存活率 (age-specific survivorship, l_x; x 為蟲齡)、齡別繁殖率 (age-specific fecundity; m_x) 及繁殖淨值 (net maternity value; V_x)，以 Sigmaplot 軟體將數據繪製成圖，以便分析比較。同時以該軟體計算不同恆溫下小黃薊馬的族群介量，包括內在增殖率 (intrinsic rate of increase; r_m)、終極增殖率 (finite rate of increase; λ)、淨增殖率 (net reproductive rate; R_0) 及平均世代時間 (mean generation time; T) 等，並且利用拔靴法 (bootstrap) 重複取樣 10,000 次以估算族群介量的標準差 (Akköprü *et al*. 2015)。

結果

不同恆溫下小黃薊馬之發育時間及累積死亡率

在16、20、24、28、32、34及36℃恆溫下，小黃薊馬飼養於檬果葉上之各未成熟期發育所需時間如表 1。小黃薊馬在不同定溫下卵期的平均發育時間為 4.1–19.1 d，長短比較相差 4.7 倍。一齡幼蟲期的平均發育時間為 1.4–5.7 d，長短比較相差 4.1 倍。二齡幼蟲期的平均發育時間為 1.3–8.2 d，長短比較相差 6.3 倍。蛹期的平均發育時間為 1.5–7.9 d，長短比較相差 5.9 倍。卵發育至成蟲的平均發育時間為 8.5–42.0 d，長短比較相差 4.9 倍。除一齡幼蟲期在 32℃時所需發育時間為最短，其餘齡期則皆是以在 34℃環境中所需發育時間為最短。

在不同恆溫下，小黃薊馬於一齡幼蟲期、二齡幼蟲期與蛹期的累積死亡率如圖 1。一齡幼蟲期以在 34℃時的累積死亡率最高為 17.52%，而在 24℃與 28℃時，則個體皆能完成發育進入二齡幼蟲期。二齡幼蟲期以在 16℃時的累積死亡率最高為 45.22%，其次是 36℃時的 39.39%。蛹期則是以在 36℃時的累積死亡率最高，達到 75.76%，其次是在 16℃時的 56.52% 與 34℃時的 45.99%。

不同溫度與各蟲期發育速率模式

將各齡期發育速率與溫度以直線迴歸分析計算個別的斜率 (b) 及截距 (a) (圖 2)，並藉以

表 1. 不同定溫下小黃薊馬在檬果上之各未成熟期平均發育所需時間。

Table 1. Mean developmental times (days, mean ± SD) of the immature stages of *Scirtothrips dorsalis* for 7 temperatures on mango.

		Developmental duration (days, Mean ± SD)				
Temp. (℃)	n	Egg	1st larva	2nd larva	Pupa	Egg-adult
16	115	19.1 ± 1.5	5.7 ± 1.6	8.2 ± 3.5	7.9 ± 2.2	42.0 ± 3.5
20	89	9.9 ± 1.6	2.9 ± 0.7	4.1 ± 1.1	4.6 ± 1.0	21.6 ± 2.0
24	85	7.1 ± 0.9	2.2 ± 0.6	2.4 ± 0.9	3.3 ± 0.6	15.0 ± 1.1
28	65	5.5 ± 0.7	1.7 ± 0.6	2.2 ± 0.9	2.6 ± 0.6	12.0 ± 0.9
32	96	4.3 ± 0.6	1.4 ± 0.5	1.9 ± 0.9	2.2 ± 0.5	9.8 ± 1.0
34	137	4.1 ± 0.5	1.7 ± 0.6	1.3 ± 0.6	1.5 ± 0.6	8.5 ± 0.8
36	33	4.5 ± 0.9	2.4 ± 0.5	2.3 ± 1.0	1.6 ± 0.7	10.5 ± 1.3

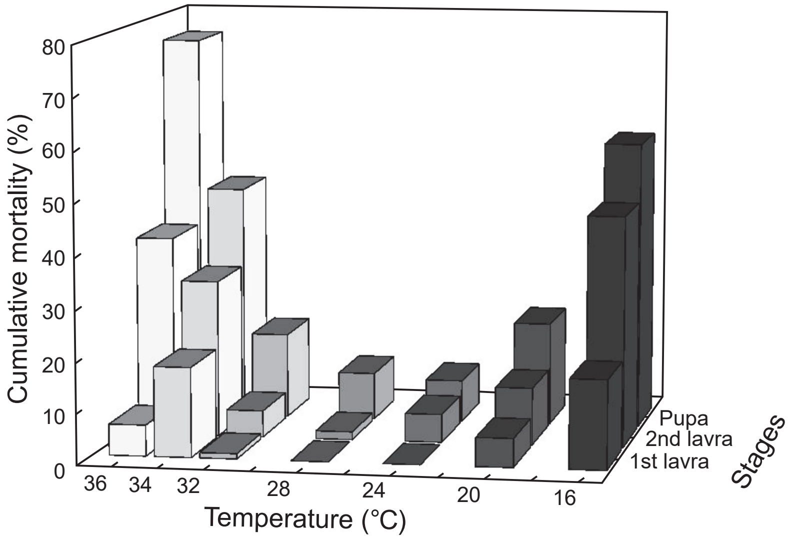


圖 1. 檬果上小黃薊馬在不同恆溫下幼蟲期與蛹期之累積死亡率。

Fig. 1. Effect of temperature on the cumulative mortality of *Scirtothrips dorsalis* in larva and pupa stage on mango.

分析各齡期的發育臨界低溫與發育總積溫 (表 2)。卵期、一齡幼蟲期、二齡幼蟲期、蛹期與整個未成熟期的發育速率與溫度間的直線迴歸分析所得 *P*-value 皆小於 0.01，表示溫度是影響發育速率的因子之一，而每個直線迴歸分析的 R^2 值皆大或等於 0.95，表示此直線迴歸具有相當的解釋度。分析卵期、一齡幼蟲期、二齡幼蟲期與蛹期的發育總積溫依序為 90.49、29.27、39.53 及 49.23 日度，而發育臨界低溫則依序為 11.1、10.5、10.2 及 9.4℃。整個未成熟期的發育總積溫為 206.14 日度，而發育臨界低溫為 10.7℃。

將各齡期發育速率與溫度另以 Lactin-2 非線性迴歸分析計算各估算介量 (圖 2)，並推算各齡期的最適發育溫度和發育臨界低溫 (表 3)。每個非線性迴歸分析的 R^2 值皆大或等於 0.93，表示非線性迴歸具有相當的解釋度。分析卵期、一齡幼蟲期、二齡幼蟲期與蛹期的發育臨界低溫依序為 10.6、10.5、10.4 與 11.0℃，最適發育溫度分別為 34.2、31.5、35.6 及 35.6℃，而發育臨界高溫分別為 38.2、37.8、36.1 與 36.0℃。整個未成熟期的發育臨界低溫為 10.6℃，最適發育溫度為 35.6℃，而發育臨界高溫為 36.1℃。

不同溫度下生命表及族群介量分析

小黃薊馬於不同恆溫下各齡期之齡別存活率 (S_{xj}) 曲線 (圖 3) 中顯示在 20、24、28、32 及 34℃的環境條件下，依序於卵期第 6、5、5、3 與 5 d 時，分別與一齡幼蟲期和二齡幼蟲期齡期相重疊。在 24℃的環境下，甚至出現在卵期第 8 d 時會同時與一齡幼蟲期、二齡幼蟲期與蛹期相重疊。不同溫度條件下各個齡期均有重疊現象，溫度越高，重疊現象越明顯。

由齡別存活率 (l_x) 之曲線 (圖 4) 可知小黃薊馬於 20、24、28、32 與 34℃下，分別在第 38、28、25、17 與 10 d 達到族群半數自然死率，而存活天數依序為 88、52、54、35 與 17 d，兩者時間皆隨著溫度升高而縮短。由齡別繁殖率 (m_x) 之曲線 (圖 4) 可以看出小黃薊馬在 20、24、28、32 與 34℃下，開始產卵的時間分別為第 19、14、11、7 與 8 d，繁殖高峰依序為第 32、20、15、18 與 14 d，結束產卵的時間依序為第 84、47、52、32 與 16 d。隨著溫度升高，小黃薊馬繁殖期與產卵高峰期有提早的現象，因而壽命有縮短現象。由齡別存活率 (l_x) 乘以齡別繁殖率 (m_x) 可以得到繁殖淨值 (V_x)，曲線下面積為該溫度下繁殖淨值的總和，其中以 28℃時的面積較大 (圖 4)。

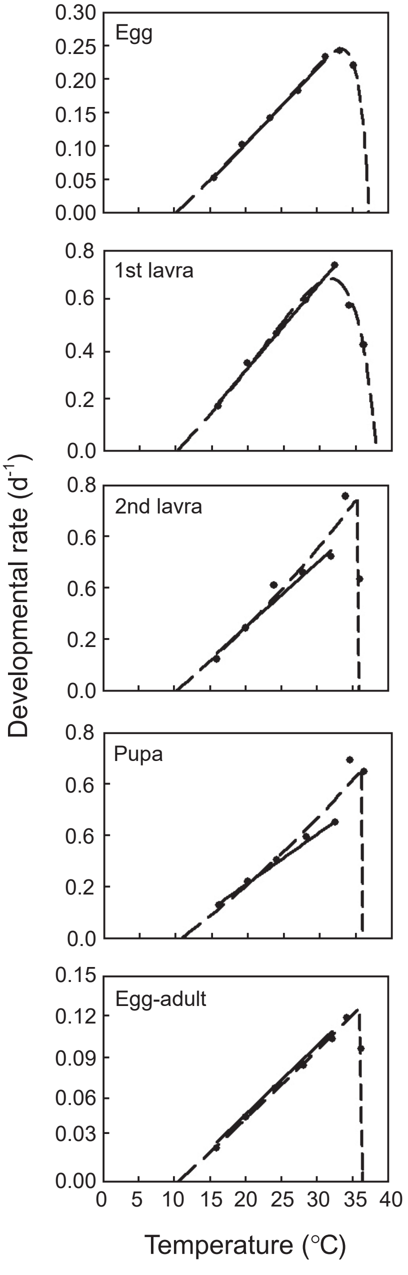


圖 2. 柑小黃薊馬在檬果上於 16–36℃下的發育速率與溫度間的關係。配合曲線：直線迴歸分析溫度範圍 16–32℃ (—) 和 Lactin-2 非線性迴歸分析溫度範圍 16–36℃ (---)。

Fig. 2. Relationships between temperature and developmental rate of *Scirtothrips dorsalis* at 16–36℃ on mango. Fitted curves: the linear regression analysis within the temperature range of 16–32℃ (—) and the Lactin-2 nonlinear regression analysis within the temperature range of 16–36℃ (---).

由兩性生命表資料分析所得族群介量如表 4，小黃薊馬於各恆溫下的內在增殖率 (r_m) 以 28℃時為 0.2009 d^{-1} 最高，其次依序是 32℃時的 0.1674 d^{-1}、34℃時的 0.1155 d^{-1} 和 24℃時的 0.1055 d^{-1}，而 20℃時的 0.0824 d^{-1} 最低。淨增殖率 (R_0) 以 28℃時 40.82 子代/♀ 最高，其次依序為 20℃時 15.08 子代/♀、32℃時 14.87 子代/♀ 和 24℃時 11.72 子代/♀，而 34℃時 4.14 子代/♀ 最低。平均世代所需時間 (T) 以 34℃時 12.15 d 最短，其次依序為 32℃時 16.03 d、28℃時 18.41 d 與 24℃時 23.13 d，而以 20℃時 32.77 d 最長。終極增殖率 (λ) 在 28℃時 1.2226 d^{-1} 為最高，其次依序是 32℃時 1.1823 d^{-1}、34℃時 1.1226 d^{-1} 和 24℃時 1.1113 d^{-1}，而 20℃時 1.0859 d^{-1} 最低。

討論

溫度對發育所需時間之影響

昆蟲的發育時間主要是受到溫度與寄主植物的影響。本研究在恆溫環境下，小黃薊馬在檬果葉上於 16℃時卵的孵化時間為 19.1 d，而 Shibao (1996) 調查小黃薊馬卵在葡萄葉上於 16℃時的孵化時間為 17.2 d，在綠茶葉上的卵於 17℃時的孵化時間為 14.1 d (Kang *et al*. 2015)，Tatara (1994) 指出小黃薊馬卵在珊瑚樹葉上於 17℃時的孵化時間為 21.3 d，由此可知寄主植物的不同是影響小黃薊馬卵孵化時間的因素之一。

本研究調查小黃薊馬於 20℃時卵發育至成蟲所需發育時間為 21.6 d，而 Li (2010) 同樣調查小黃薊馬在檬果葉上於 20℃時為 22.3 d，兩者所需時間僅相差 0.7 d。此外，該報告中小黃薊馬於 25℃時發育時間為 14.0 d，介於本研究中 24℃時的 15.0 d 與 28℃時的 12.0 d 之間，並且於 30℃時發育時間為 11.7 d，亦介於本研究中 28℃時的 12.0 d 與 32℃時的 9.8 d 之間，兩篇研究因供試作物同為檬果，所以試驗結果相近。Seal *et al*. (2010) 於 26 ± 1℃的恆溫下，調查小黃薊馬在不同寄主植物上從卵發育至成蟲所需時間，結果顯示小黃薊馬在番茄上的發育所需時間為 20.6 d，在菜豆上為 20.3

表 2.　小黃薊馬在檬果上溫度 (X) 與發育速率 (Y) 之直線模式。

Table 2.　Linear model for temperature (X) and developmental rates (Y) of *Scirtothrips dorsalis* on mango.

Life stages	Regression equation	R^2	*P*-value	Thermal summation (degree-day)	Low temperature threshold (℃)
Egg	Y = -0.12315 + 0.01105X[z]	0.998	0.0000	90.49 ± 2.35	11.1 ± 0.36
1st larva	Y = -0.35749 + 0.03416X	0.996	0.0000	29.27 ± 1.00	10.5 ± 0.50
2nd larva	Y = -0.25753 + 0.02530X	0.950	0.0047	39.53 ± 5.21	10.2 ± 1.97
Pupa	Y = -0.19127 + 0.02031X	0.994	0.0002	49.23 ± 2.22	9.4 ± 0.70
Egg-adult	Y = -0.05192 + 0.00485X	0.997	0.0000	206.14 ± 6.74	10.7 ± 0.47

[z] Y = *a* + *b*X, where Y is the rate of development [1/developmental period (d)] and X is the temperature (℃).

表 3.　小黃薊馬在檬果上溫度與發育速率之 Lactin-2 模式。

Table 3.　Lactin-2 model for temperature and developmental rates of *Scirtothrips dorsalis* on mango.

Life stage	Parameter				R^2	Low temperature threshold (℃)	Optimal temperature (℃)
	ρ[z]	T_L[y]	ΔT[x]	λ[w]			
Egg	0.0090	40.2784	1.3636	-1.0997	0.998	10.6	34.2
1st larva	0.0239	40.2417	3.1224	-1.2844	0.970	10.5	31.5
2nd larva	0.0189	36.1465	0.0811	-1.2183	0.930	10.4	35.6
Pupa	0.0174	36.1324	0.0895	-1.2115	0.934	11.0	35.6
Egg-adult	0.0045	36.3196	0.0877	-1.0488	0.996	10.6	35.6

[z] Composite value for critical enzyme-catalyzed biochemical reactions.
[y] Thermal maximum.
[x] Temperature range over which thermal breakdown becomes the overriding influence.
[w] Curve to intersect the abscissa at suboptimal temperatures.

d，在南瓜上為 20.2 d，在茄子上為 19.9 d，在玫瑰上 18.4 d，在辣椒上為 17.8 d，相較於本研究中小黃薊馬在檬果葉上 24℃時僅需 15.0 d，發育時間明顯比在其他作物上短，由此推論檬果葉可能更適合小黃薊馬發育生長。

本研究中小黃薊馬在檬果葉上各時期所需的發育時間，於 16–34℃之間呈現隨著溫度上升而縮短，而超過 34℃時其平均發育時間有增加的趨勢。前人研究小黃薊馬在不同寄主植物如綠茶、珊瑚樹與葡萄上時，亦得到發育時間隨溫度上升而縮短的相同結論 (Tatara 1994; Shibao 1996; Kang *et al*. 2015)。

溫度對發育速率之影響

以直線迴歸分析小黃薊馬在檬果葉上卵期的發育臨界低溫與發育總積溫分別為 11.1℃與 90.49 日度，而 Kang *et al*. (2015) 分析小黃薊馬的卵期在綠茶葉片上的發育臨界低溫與發育總積溫分別為 9.8℃與 101.5 日度。由於在檬果葉上小黃薊馬卵的發育臨界低溫比在綠茶葉上高，因此在低溫的環境下小黃薊馬的卵在檬果上所需發育時間較長，但在檬果葉上小黃薊馬卵所需的發育總積溫較少，因此在高溫的環境下所需發育時間相對較短。

小黃薊馬在檬果葉上整個未成熟期的發育臨界低溫為 10.7℃，其發育總積溫為 206.14 日度，此結果與 Li (2010) 所分析小黃薊馬在檬果葉上的發育臨界低溫為 11.0℃，其發育總積溫為 208.4 日度相近。Tatara (1994) 在報告中指出小黃薊馬在珊瑚樹葉上的發育臨界低溫為 9.7℃，發育總積溫為 265 日度，相較於本研究的結果，在發育臨界低溫較低，而所需發育總積溫較多，推論或許是寄主植物種類的不同及該研究試驗地區位於為溫帶，導致小黃薊馬的發育臨界低溫與所需發育總積溫與本研究略有所不同。

本研究以 Lactin-2 非線性迴歸分析推算整個未成熟期的發育臨界低溫為 10.6℃，此結果

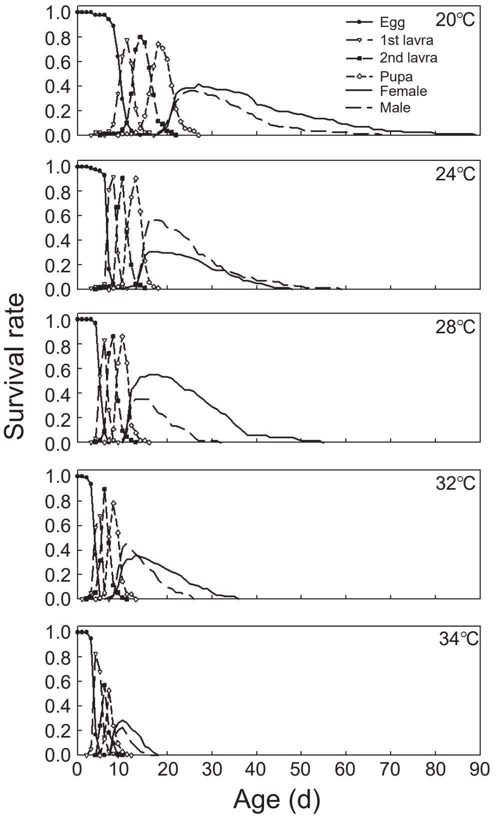


圖 3. 不同恆溫下小黃薊馬各齡期齡別存活率。

Fig. 3. Age-stage-specific survival rate of *Scirtothrips dorsalis* at various constant temperatures.

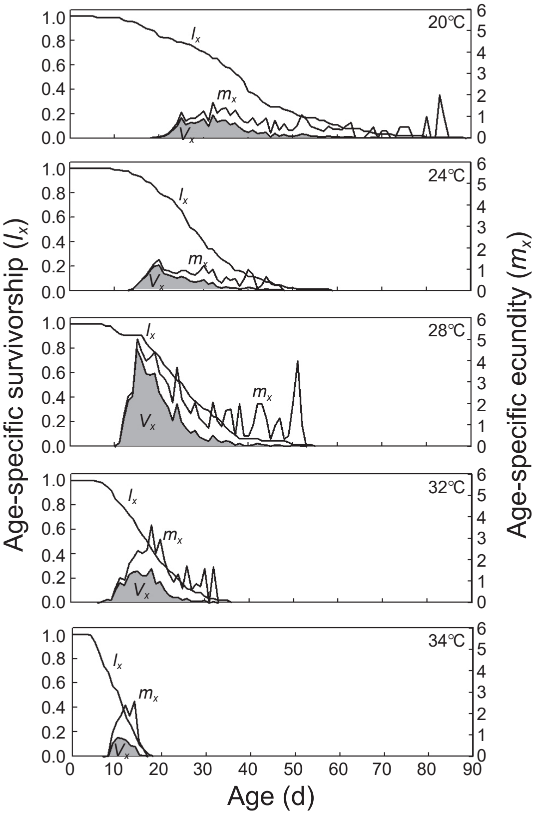


圖 4. 不同恆溫下小黃薊馬之齡別存活率 (l_x)、齡別繁殖率 (m_x) 及繁殖淨值 (V_x)。。

Fig. 4. Age-specific survivorship (l_x), fecundity (m_x) and net maternity value (V_x) of *Scirtothrips dorsalis* at various constant temperatures.

表 4. 小黃薊馬於 5 種溫度下在檬果上之族群介量。

Table 4. Population parameters of *Scirtothrips dorsalis* at 5 temperatures on mango.

Temp. (℃)	Intrinsic rate of increase (r_m) (d^{-1})	Net reproductive rate (R_0) (offspring/♀)	Mean generation time (T) (d)	Finite rate of increase (λ) (d^{-1})
20	0.0824 (0.0005)[z]	15.08 (2.46)	32.77 (0.52)	1.0859 (0.0054)
24	0.1055 (0.0088)	11.72 (2.39)	23.13 (0.61)	1.1113 (0.0098)
28	0.2009 (0.0081)	40.82 (5.50)	18.41 (0.31)	1.2226 (0.0099)
32	0.1674 (0.0112)	14.87 (2.63)	16.03 (0.36)	1.1823 (0.0132)
34	0.1155 (0.0158)	4.14 (0.77)	12.15 (0.18)	1.1226 (0.0177)

[z] Standard error (SE) is estimated by using Bootstrap method.

於直線迴歸分析所得結果及 Li (2010) 的結果相近。由 Lactin-2 非線性迴歸分析推算整個未成熟期的最適發育溫度為 35.6℃，該結果明顯與 Tatara (1994) 在珊瑚樹上飼養小黃薊馬的觀察結果不同，該報告中指出在 33℃以上小黃薊馬幼蟲期即無法完成發育，而到 36℃時小黃薊馬的卵無法孵化。但在本研究中於 34℃時小黃薊馬可以完成發育，並且有雌成蟲產卵，於 36℃時小黃薊馬依舊可以完成發育，但羽化之成蟲無雌成蟲，因此推論小黃薊馬在台灣已逐漸適應高於 33℃的環境。然而在溫度與發育速率之間的迴歸分析中，最適發育溫度僅能說明該溫度為預估小黃薊馬發育速率最快的溫度，但是高溫通常也伴隨著較高的死亡率，因此若要分析溫度對族群增長的影響，應以生命表分析來推算各族群介量，方能精準描述溫度對族群的影響。

生命表分析及其族群介量

由齡期齡別存活曲線中得知，小黃薊馬在 5 種溫度下齡期皆有重疊的現象，這表示在自然界中可以於同一時間觀察到各齡期的小黃薊馬，且隨著溫度升高重疊越明顯，顯示溫度升高導致小黃薊馬發育會有提前的現象。由齡別繁殖率曲線中得知，小黃薊馬會隨著溫度升高而提前進入繁殖期，且曲線呈現右偏的趨勢，因此族群增長的潛力集中於繁殖期前半段，故能夠在短時間內建立大型族群，對作物快速造成嚴重的為害。5 種不同溫度下繁殖淨值面積以 28℃最大，表示 28℃對小黃薊馬族群貢獻度較大，此結論與族群介量中於 28℃時淨繁殖率 (R_0) 最高相同。

小黃薊馬在檬果葉的族群介量中，內在增殖率 (r_m) 均大於 0，顯示小黃薊馬的族群在供試溫度下均呈正成長，於 20–28℃時隨著溫度上升而增加，在 28℃時 0.2009 d^{-1} 為最大，之後 28–34℃時隨溫度上升而降低。淨繁殖率 (R_0) 為族群每世代平均增殖的倍數，即一隻個體一生所繁殖的平均子代數，以 28℃時增加 40.82 倍明顯高於其他溫度。平均世代時間隨著溫度上升而縮短，以 34℃為 12.15 d 最短，此結果與 34℃時小黃薊馬發育所須時間最短相同。終極增殖率 (λ) 與內在增殖率 (r_m) 的關係為 $\lambda = e^{r}$，故 λ 的變化與 r_m 相似，本研究中 λ 皆大於 1，顯示族群為正成長，且以 28℃時 1.2226 d^{-1} 為最高，之後隨溫度上升而下降。Seal *et al*. (2010) 於 25℃時估算小黃薊馬在辣椒與玫瑰的生命表族群介量，相較於本研究中於 24℃時的族群介量，小黃薊馬在辣椒上的內在增殖率、淨增殖率與終極增殖率與在檬果上較接近，但平均世代時間仍以在檬果葉上較短。由此顯示，檬果較適合小黃薊馬族群增長。

綜合溫度對小黃薊馬個體與族群的影響，當環境溫度在 34℃以下時，隨著溫度上升，小黃薊馬個體的發育速率就越快，但是幼蟲死亡率增高且成蟲壽命相對縮短，且總產卵量以 28℃時最多 (Chen *et al*. 2013)。因此以兩性生命表估算不同溫度時之族群介量，發現在 28℃時為最適合小黃薊馬族群增長的溫度，且由 Lactin-2 非線性迴歸分析中得知 36.1℃為小黃薊馬的發育臨界高溫，此與 Chen *et al*. (2013) 指出台南地區小黃薊馬在檬果園內 2–6 月為其發生高峰期的情況相符合。故當環境氣溫達 24℃時，檬果園內應該開始進行小黃薊馬的管理工作，以免當溫度繼續上升時，對檬果品質造成嚴重影響。

引用文獻

Affandi, A. and C. R. Medina. 2013. Age structure and sex ratio of thrips *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) associating with mango agroecosystem in east Java, Indonesia. Agrivita 35:227–236.

Akköprü, E. P., R. Atlıhan, H. Okut, and H. Chi. 2015. Demographic assessment of plant cultivar resistance to insect pests: A case study of the dusky-veined walnut aphid (Hemiptera: Callaphididae) on five walnut cultivars. J. Econ. Entomol. 108:378–387.

Aliakbarpour, H., M. R. Che Salmah, and H. Dieng. 2010. Species composition and population dynamics of thrips (Thysanoptera) in mango orchards of northern peninsular Malaysia. Environ. Entomol. 39:1409–1419.

Campbell, A., B. D. Frazer, N. Gilbert, A. P. Gutierrez, and M. Mackauer. 1974. Temperature requirements of some aphids and their parasites. J. Appl. Ecol. 11:431–438.

Chen, Y. J., F. C. Lin, Y. C. Chiu, and H. T. Shih. 2013. Effects of temperature on development and reproduction of *Scirtothrips dorsalis* Hood on mango. J. Taiwan Agric. Res. 62:351–359.

Chi, H. 1988. Life-table analysis incorporating both sexes and variable development rates among individuals. Environ. Entomol. 17:26–34.

Chi, H. 2013. TWOSEX-MSChart: A computer program for the age-stage, two-sex life table analysis. http://140.120.197.173/Ecology/Download/Twosex-MSChart-exe-B100000.rar (visit on 10/5/2018)

Chiou, K. D. and W. L. Lee. 2012. Mango breeding in Taiwan. p.9–20. *in*: Proceedings of the Symposium on Mango Industry Development in Taiwan. June 28, 2012. Kaohsiung, Taiwan. Taiwan Agric. Res. Inst., Taichung, Taiwan. (in Chinese with English abstract)

Colinet, H., B. J. Sinclair, P. Vernon, and D. Renault. 2015. Insects in fluctuating thermal environments. Annu. Rev. Entomol. 60:123–140.

Kang, S. H., J. H. Lee, and D. S. Kim. 2015. Temperature-dependent fecundity of overwintered *Scirtothrips dorsalis* (Thysanoptera: Thripidae) and its oviposition model with field validation. Pest Manag. Sci. 71:1441–1451.

Kumar, V., G. Kakkar, C. L. McKenzie, D. R. Seal, and L. S. Osborne. 2013. An overview of chilli thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) biology, distribution and management. p.53–77. *in*: Weed and Pest Control- Conventional and New Challenges. (Larramendy, M. L. ed.) IntechOpen. Rijeka, Croatia. 205 pp.

Lactin, D. J., N. J. Holliday, D. L. Johnson, and R. Craigen. 1995. Improved rate model of temperature-dependent development by arthropods. Envion. Entomol. 24:68–75.

Li, Y. Z. 2010. The population dynamic, life history and insecticide screening of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae). Master Thesis, Department of Plant Medicine, National Pingtung University of Science and Technology. Pingtung, Taiwan. 76 pp. (in Chinese with English abstract)

Lin, F. C., Y. C. Chiu, H. T. Shih, and C. L. Wang. 2010. Monitoring and integrated management of small insect pest on mango. p.99–107. *in*: Proceedings of the Symposium on Production and Pest Management of Mango. September 23, 2010. Taichung, Taiwan. Taiwan Agric. Res. Inst., Taichung, Taiwan. (in Chinese with English abstract)

Morse, J. G. and M. S. Hoddle. 2006. Invasion biology of thrips. Annu. Rev. Entomol. 51:67–89.

Quinn, B. K. 2017. A critical review of the use and performance of different function types for modeling temperature-dependent development of arthropod larvae. J. Therm. Biol. 63:65–77.

Seal, D. R., W. Klassen, and V. Kumar. 2010. Biological parameters of *Scirtothrips dorsalis* (Thysanoptera: Thripidae) on selected hosts. Environ. Entomol. 39:1389–1398.

Shibao, M. 1996. Effects of temperature on development of the chillie thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), on grape. Appl. Entomol. Zool. 31:81–86.

Shih, H. T., H. H. Hao, Y. C. Chiu, F. C. Lin, and M. M. Yang. 2013. A revised and annotated checklist of insects and mites of mangos from Taiwan. Formosan Entomol. 33:27–51. (in Chinese with English abstract)

Tatara, A. 1994. Effect of temperature and host plant on the development, fertility and longevity of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae). Appl. Entomol. Zool. 29:31–37.

Wei, M. Y., C. K. Lo, Y. Y. Chuang, and N. T. Chang. 2011. Catch efficiency of the sticky trap for *Scirtothrips dorsalis* Hood in the mango orchard. Formosan Entomol. 31:339–349. (in Chinese with English abstract)

Wen, H. C. and W. J. Wu. 2010. Relationship between population occurrence of mango insect pests and climate factors. p.43–54. *in*: Proceedings of the Symposium on Production and Pest Management of Mango. September 23, 2010. Taichung, Taiwan. Taiwan Agric. Res. Inst., Taichung, Taiwan. (in Chinese with English abstract)

Temperature-dependent Development and Life Table of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) on Mango

Hsin-Shun Lai[1], Yi-Ju Chen[2], Yi-Chung Chiu[3], and Feng-Chyi Lin[4,*]

Abstract

Lai, H. S., Y. J. Chen, Y. C. Chiu, and F. C. Lin. 2018. Temperature-dependent development and life table of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) on mango. J. Taiwan Agric. Res. 67(2):181–190.

Scirtothrips dorsalis Hood was raised at 16, 20, 24, 28, 32, 34 and 36℃ on mango (*Mangifera indica* L.) to observe the effect of temperature on the developmental times of the immature stages and estimate the population parameters of *S. dorsalis* at 20, 24, 28, 32 and 34℃ . The results showed that developmental time of egg, first larva, second larva, pupa and egg to adult stage were 4.1–19.1 d, 1.4–5.7 d, 1.3–8.2 d, 1.5–7.9 d and 8.5–42.0 d at 16–36℃ , respectively. The thermal summation was 206.14 degree-days and the low temperature threshold was 10.7℃ as calculated by linear regression analysis. The low temperature threshold was 10.6℃ and the optimal temperature was 35.6℃ as calculated by Lactin-2 nonlinear regression analysis. Population parameters at different temperatures on *S. dorsalis* showed that both the intrinsic rate of increase (r_m) and the finite rate of increase (λ) were the highest at 28℃ ($r_m = 0.2009$ d^{-1}, $\lambda = 1.2226$ d^{-1}), and the lowest was at 20℃ ($r_m = 0.0824$ d^{-1}, $\lambda = 1.0859$ d^{-1}). The reproductive rate (R_0) was the largest at 28℃ ($R_0 = 40.82$ offspring/♀), and the smallest was at 34℃ ($R_0 = 4.14$ offspring/♀). The mean generation time (T) was the longest at 20℃ ($T = 32.77$ d), and the shortest at 34℃ ($T = 12.15$ d).

Key words: *Scirtothrips dorsalis*, Mango, Temperature, Developmental rate, Life table.

Received: July 24, 2017; Accepted: September 30, 2017.
* Corresponding author, e-mail: fclin@tari.gov.tw
1 Assistant Research Fellow, Department of Plant Protection, Fengshan Tropical Horticultural Experiment Branch, Taiwan Agricultural Research Institute, Kaohsiung, Taiwan, ROC.
2 Assistant Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.
3 Contract Assistant Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.
4 Associate Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):191–208 (2018)
DOI: 10.6156/JTAR.201806_67(2).0005 研究報告

玉米褪綠斑駁病毒 (*Maize chlorotic mottle virus*) 之親緣分析與台灣之發生調查

周建銘[1] 陳君弢[2] 簡伊萱[3] 蔡錦慧[3] 陳金枝[1] 林鳳琪[4] 陳怡如[5] 鄧汀欽[6,*]

摘要

周建銘、陳君弢、簡伊萱、蔡錦慧、陳金枝、林鳳琪、陳怡如、鄧汀欽。2018。玉米褪綠斑駁病毒 (*Maize chlorotic mottle virus*) 之親緣分析與台灣之發生調查。台灣農業研究 67(2):191–208。

自雲林縣虎尾地區採集具褪綠、黃化及褐化乾枯病徵之玉米病害樣本，並將其機械接種於甜玉米 ‘Honey-236’ 可產生類似褪綠斑駁病徵，並獲得一個分離株 (稱為 NFU2)。樣本以簡併式引子對進行反轉錄聚合酶鏈鎖反應 (reverse transcriptase polymerase chain reaction; RT-PCR)，可增幅出預期大小 (1.4 kb) 產物，經解序後序列與玉米褪綠斑駁病毒 (*Maize chlorotic mottle virus*; MCMV) 中國 Yunnan3 分離株 (Acc. No. JQ982469) 相同度達 99%。將 MCMV NFU2 分離株全基因體解序後，其全長為 4,436 nt，經親緣分析後 MCMV 共可分為美國分離株、中國分離株、東非分離株及台灣分離株等四個分群；若將其鞘蛋白序列進行親緣分析，則可發現泰國之 MCMV 分離株應為近年於亞非大發生 MCMV 之共同起源。依解序所得 MCMV NFU2 分離株之鞘蛋白序列，構築於表現載體後大量表現以製備其多元抗血清，該多元抗血清經測試可用於田間樣本之酵素免疫分析法 (enzyme-linked immunosorbent assay; ELISA) 檢測。此外，利用其鞘蛋白序列設計專一性引子對 MCMV-g3514F/MCMV-g4014R，可以 RT-PCR 於單隻玉米薊馬中檢測出 MCMV，可作為後續媒介昆蟲傳播 MCMV 的機制研究之用。於 2014–2015 年間利用 MCMV 及甘蔗嵌紋病毒 (*Sugarcane mosaic virus*; SCMV) 抗體於台灣各地玉米栽培區調查，共檢測 306 個樣本，結果顯示 MCMV 罹病率達 79.7%，MCMV 與 SCMV 複合感染造成之玉米致死性壞疽 (maize lethal necrosis; MLN) 罹病率為 31.7%；檢測樣本中，白玉米、糯玉米、青割玉米、硬質玉米及 7 種甜玉米品種皆可檢出 MCMV，食用玉米中「華珍」之罹病率較低，但亦達 60%，青割玉米及硬質玉米 MCMV 罹病率平均達 31.6%。本研究為台灣 MCMV 分離株之基因體全長度解序、親緣分析、檢測試劑開發及病害調查之首次報告。

關鍵詞：玉米褪綠斑駁病毒、甘蔗嵌紋病毒、親緣分析、檢測試劑、病害調查。

前言

玉米 (*Zea mays* L.) 為禾本科玉米屬的一年生草本作物，原產於中美洲墨西哥，是目前世界上產量最大的糧食及飼料作物。台灣的玉米栽培始紀錄於 1717 年，依據農業統計年報資料顯示，1988 年台灣玉米栽培面積高達 82,183 ha，之後逐漸減少，至 2012 年硬質玉米及食用玉米栽培面積共僅 16,651 ha；近幾年來硬質玉米栽培面積明顯增加，2015 年度達 15,135 ha，食用

投稿日期：2017 年 5 月 22；接受日期：2017 年 10 月 23 日。
[*] 通訊作者：tcde@tari.gov.tw
[1] 農委會農業試驗所植物病理組助理研究員。台灣 台中市。
[2] 農委會動植物防疫檢疫局新竹分局技士。台灣 桃園市。
[3] 農委會農業試驗所植物病理組研究助理。台灣 台中市。
[4] 農委會農業試驗所應用動物組副研究員。台灣 台中市。
[5] 農委會農業試驗所應用動物組助理研究員。台灣 台中市。
[6] 農委會農業試驗所植物病理組研究員。台灣 台中市。

玉米栽培面積也增加至 12,616 ha。往年台灣玉米病毒病危害僅有玉米矮化嵌紋病毒 B 型系統 (*Maize dwarf mosaic virus* B strain; MDMV-B)，現在分類屬於甘蔗嵌紋病毒 (*Sugarcane mosaic virus*; SCMV) 的 SCMV-MDB strain (Deng 1985; Deng *et al*. 2014b) 及玉米條紋病毒 (*Maize stripe virus*; MSpV) (Chao *et al*. 1988) 的發生紀錄，兩者皆於栽培面積大增時被發現。由於栽培習慣改變，現今田間雖偶有發生，但並未有大面積感染情形。近年來玉米栽培面積再度明顯增加，新發生的玉米褪綠斑駁病毒 (*Maize chlorotic mottle virus*; MCMV) (Deng *et al*. 2014a; Chou *et al*. 2015) 造成大面積的玉米被感染，使產量及品質嚴重下降。

MCMV 是 *Tombusviridae* 科 *Machlomovirus* 屬唯一的一個種 (Scheets 2002)，MCMV 感染玉米引起之病徵主要為葉脈有平行條紋斑駁、葉片褪綠且全葉會有不同程度之黃化情形，嚴重時斑駁病徵癒合產生大面積之褪綠斑，植株可能矮化畸形，亦可能造成雄花穗節間縮短；若於成株時感染，則矮化情形不明顯，但雄花穗抽穗後，雄花穗及苞穗會有褐化乾枯情形、苞葉上亦可見有斑駁病徵。受害植株結穗充實率不佳，越早期感染，充實率越差 (Uyemoto 1983)。此病毒於 1974 年在南美洲秘魯玉米栽培區被首次發現 (Castillo & Hebert 1974)，爾後十年間於美洲地區，如美國、墨西哥、巴西、阿根廷等地玉米栽培區陸續有 MCMV 的發現報導 (Niblett & Claflin 1978; Teyssandier *et al*. 1982; Uyemoto 1983; Delgadillo Sanchez & Gaytan Beltran 1987)，1990 年於夏威夷地區首次發現 MCMV 危害，並嚴重影響當地玉米產業，亦凸顯了 MCMV 經種子長距離傳播的可能性 (Jensen *et al*. 1991)。亞洲地區的 MCMV 最早發生於泰國，但危害範圍較為侷限 (Klinkong & Sutabutra 1982)；直至 2009 年，中國雲南省亦首次發現 MCMV，並於 2011 年正式報導 (Xie *et al*. 2011)。隨後陸續在中國四川省、台灣、肯亞、盧安達、衣索比亞、剛果民主共和國、坦尚尼亞等國家廣泛被報導且嚴重發生 (Xie *et al*. 2011; Wangai *et al*. 2012; Adams *et al*. 2014; Deng *et al*. 2014a; Lukanda *et al*. 2014; Mahuku *et al*. 2015b; Fentahun *et al*. 2017)，2016 年於南美洲厄瓜多爾亦有 MCMV 的首次報導 (Quito-Avila *et al*. 2016)。

MCMV 能夠快速擴散且成為玉米生產的限制因子的主要原因是：(1) 具種子傳毒能力可行長距離傳播，雖其種傳能力極低，約僅 0.04% (Jensen *et al*. 1991)，但 Mahuku *et al*. (2015a) 以反轉錄聚合酶鏈鎖反應 (reverse transcriptase polymerase chain reaction; RT-PCR) 方式檢測從 MCMV 感染玉米植株採收之種子，其種子帶毒率約 72%，且在非洲當地購買的玉米種子即可檢測到 MCMV。自 2010 年開始，中國陸續於美國、德國進口玉米種子中測得 MCMV，其傳毒率分別為 0.33%、0.5%，而於泰國進口玉米種子可測得種子帶毒率為 2% (Gong *et al*. 2010; Liu *et al*. 2011; Lei *et al*. 2013)；MCMV 藉由種子傳毒，將可迅速傳播至新發生地區或其他國家。(2) 媒介昆蟲種類多樣且可迅速傳播 MCMV 於鄰近栽培區，目前已知包含多種鞘翅目金花蟲科 (Chrysomelidae) 甲蟲可以永續型方式傳播 MCMV (Nault *et al*. 1978) 及玉米薊馬 (*Frankliniella williamsi* Hood) (Jiang *et al*. 1992; Cabanas *et al*. 2013)、西方花薊馬 [*F. occidentalis* (Pergande)] (Zhao *et al*. 2014) 等 2 種薊馬以半持續型方式傳播 MCMV。Mahuku *et al*. (2015a) 的報告顯示，梳缺花薊馬 (*F. schultzei* Trybom)、蔥薊馬 [*Thrips tabaci* (Linderman)] 也可傳播 MCMV；在合適的環境下，媒介昆蟲可迅速增長繁殖並造成 MCMV 的大面積發生。(3) MCMV 可與 SCMV 等 potyviruses 複合感染造成玉米致死性壞疽 (maize lethal necrosis; MLN 或稱 corn lethal necrosis; CLN)，玉米遭 MLN 危害，其 MCMV 的病毒量較 MCMV 單獨感染植株上升 1.7 至 11.2 倍，MLN 危害植株較 MCMV 單獨感染者葉綠素含量下降約 5 倍 (Goldberg & Brakke 1987; Scheets 1998)。在外觀上，MLN 感染更容易造成嚴重黃化的病徵，並發展成葉緣及葉尖乾枯情形，且可造成 90% 以上的產量損失，苗期感染會造成矮化且絕收之情形 (Niblett & Claflin 1978; Uyemoto 1983)。自 2011 年以來玉米病毒病害嚴重發生地區，皆有大面積的 MLN 發生紀錄 (Xie *et al*. 2011; Wangai *et al*. 2012;

Adams *et al*. 2014; Deng *et al*. 2014a; Mahuku *et al*. 2015a; Mahuku *et al*. 2015b; Quito-Avila *et al*. 2016)。

MCMV 病毒在台灣自 2014 年首次報導後，目前仍缺乏台灣分離株的病毒親源分析，相關的病毒檢測工具亦待開發，而 MCMV 病毒在台灣的病害流行及生態學等相關資料仍需進一步研究。本研究針對在台灣發生之 MCMV 分離株之全長度序列解序，分析其與近年來各地區大發生之 MCMV 病毒之相關性，同時亦依據病毒鞘蛋白序列分析病毒親緣關係，並依鞘蛋白序列設計表現載體開發免疫血清檢測試劑，利用鞘蛋白核酸序列設計開發分子檢測引子，供後續相關研究使用。本研究亦藉由市售免疫檢測試劑，以及自行開發之免疫檢測血清，調查台灣 MCMV 病毒及其複合 SCMV 病毒發生情形，初步掌握 MCMV 病毒在台灣發生之現況。

材料與方法

病毒分離及發生調查

2014 年 2 月自雲林縣虎尾鎮採集呈現褪綠、斑駁及黃化病徵之疑似病毒病為害之玉米樣本，部分葉片周圍呈現壞疽情形。將樣本採回後取部分病葉進行機械接種以分離病毒 (Deng 1985)。取其葉片，以 1 : 10 (W : V) 比例之病組織汁液與磷酸緩衝液 (0.01 M $KHPO_4$, pH 7.0) 於研磨袋混合後進行研磨，研磨後粗汁液接種於灑有些許 400 目金鋼砂之甜玉米 (*Zea mays* var. *rugosa* cv. ‘Honey-236’) 葉片，出現斑駁病徵之玉米植株葉片以 10× 系列稀釋接種於甜玉米 ‘Honey-236’，每個稀釋濃度接種 10 棵甜玉米，接種後觀察其發病比例。

分離病毒時以 500× 磷酸緩衝液與接種發病株之葉片混合後研磨，研磨後粗汁液接種於甜玉米 ‘Honey-236’，待其出現病徵後重複上述稀釋及接種條件。反覆接種 3 次，之後獲得之病毒視為一分離株。為製備接種源，將單一分離株接種於超甜玉米 ‘Honey-236’ 於植株成長至第 10 葉後，將其葉片切碎至 0.04 cm^2 大小後放置於含無水氯化鈣 ($CaCl_2$) 之培養皿內，於 4℃乾燥組織，至組織完全乾燥後置於含無水氯化鈣之 15 mL 塑膠試管內備用。

為調查 MCMV 於台灣發生情形，針對雲林縣、嘉義縣、台南市、高雄市、花蓮縣及台東縣、苗栗縣及彰化縣等各地玉米栽培區進行調查，採樣時取明顯有黃化、褪綠病徵葉片或上位葉進行檢測。於雲林縣採集時，將玉米田區內帶有薊馬之植株帶回並鑑定薊馬種類。

RNA 抽取及反轉錄聚合酶鏈鎖反應

將 0.1 g 疑似病毒病為害玉米葉片樣本，以液態氮研磨葉片成粉狀後，以小量全 RNA 純化試劑組 (total RNA extraction kit/Mini, Vio-Gene-Biotek Corp., New Taipei City, Taiwan) 進行病組織 RNA 萃取。以獲得之病組織全 RNA 作為模板，進行 RT-PCR。分別取 3 對簡併式引子對，包括 *Potyvirus* 屬病毒簡併式引子對 Hrp5/Pot1 (Pappu *et al*. 1993)、*Potexvirus* 屬病毒簡併式引子對 Potex1RC/Potex5 (van der Vlugt & Berendsen 2002) 及自行設計之 *Tenuivirus* 屬病毒簡併式引子對 Tenui-DF1/Tenui-DR1 與病組織全 RNA 進行 cDNA 合成，條件如下：病組織全 RNA 2–4 μL、2.5 mM dNTP 1 μL、10 μM 簡併式引子正反股各 1 μL，加入 diethyl pyrocarbonate (DEPC) 處理的水至 12 μL。於 65℃條件下 5 min，再於冰上靜置 1 min 以上，然後加入下述試藥：0.1 M DTT 2 μL、RNase OUT 1 μL、5× first strand buffer 4 μL，於 42℃條件下靜置 2 min。其後，加入 Super script™ II (Thermo Fisher Scientific Inc. Waltham, MA, USA) (200 units μL^{-1}) 1 μL，於 42℃條件作用 50 min 以合成 cDNA，然後於 70℃條件下作用 15 min 以去除酵素活性。獲得 cDNA 後，分別使用相應之簡併式引子對進行 touchdown polymerase chain reaction (PCR)，PCR 反應組成如下：Taq DNA polymerase 2× master mix with red (Ampliqon) 10 μL，簡併式正反股引子各 1 μL，cDNA 2 μL，補水至 20 μL。touchdown PCR 條件為 94℃ 5 min (94℃ 30 s，50℃溫度遞減至 43℃ 30 s，72℃ 2 min) 進行 35 個循環，72℃ 10 min 後靜置於 4℃。

為了檢測玉米薊馬之玉米褪綠斑駁病毒帶毒情形，使用 Genefisher2 (Giegerich *et al*. 1996) (http://bibiserv.techfak.uni-bielefeld.de/

genefisher2/) 線上 PCR 引子對設計程式，依照不同 MCMV 病毒分離株 (Yunnan11, Acc. No. KF010583; Yunnan2, Acc. No. JQ982468; Sichuan, Acc. No. JQ982470; Yunnan3, Acc. No. JQ982469; Kenya, Acc. No. JX286709; Kansas, Acc. No. NC_003627; Nebraska, Acc. No. EU358605) 鞘蛋白保守性區域序列設計出引子對 MCMV-g3514F/MCMV-g4014R 作為 MCMV 病毒專一性 RT-PCR 檢測用，檢測時使用 Accupower® RT-PCR PreMix (Bioneer Corp., Seoul, Korea) 試劑組，RT-PCR 反應條件如下：試管內加入 RNA 1–4 μL 及 10 μM 正反股引子各 1 μL，置於 70℃ 5 min 後，置於冰上，之後將其與試劑組 Premix 混合並補 DEPC 水至 20 μL。混合後，於 42℃條件作用 1 h 以合成 cDNA。然後於 94℃條件下作用 5 min 以去除酵素活性，之後進行 PCR 反應。先進行 94℃ 5 min (94℃ 30 s, 55℃ 30 s, 72℃ 30 s) 進行 35 個循環，72℃ 10 min 後靜置於 4℃。將 RT-PCR 後產物以 1.5% 洋菜膠，在 0.5× TAE，50 V 條件下進行電泳，最後以 EtBr 染色 10 min 後，以清水退染，並以 Vilber Lourmat 照膠系統搭配 Infinity Capt. 軟體 (version 14.2, Vilber Lourmat, Marne la Vallee, France) 拍照及分析。

病毒表現載體製作與抗血清製備

利用 pET28b (+) 表現載體系統以製備 MCMV 病毒抗血清，依據定序所得 MCMV 鞘蛋白 (Coat protein; CP) 全長序列，於鞘蛋白序列 5’ 端及 3’ 端分別設計引子對 (NdeI-MCMVCP-F/MCMVCP-SalI-R) 以增加鞘蛋白序列之 5’ 端 NdeI 切位及 3’ 端 SalI 切位。將增幅之具載體切位之鞘蛋白序列產物，依照 T&ATM cloning kit (Yeastern Biotech Co. Ltd., New Taipei City, Taiwan) 的操作步驟插入 T&A 載體獲得 pMCMVCP 載體，並次選殖於 pET28b (+) 載體後轉型入 *Escherichia coli* strain Rosetta™ (DE3) 勝任細胞 (Novagen, Inc., Madison, WI, USA)。

將具 MCMV 鞘蛋白表現載體之 *E. coli* strain Rosetta™ (DE3) 培養於 M9 培養液 (Li *et al*. 1998)，並以 1 mg mL^{-1} 之異丙基-β-D- 硫代半乳糖苷 (isopropyl β-D-thiogalactoside; IPTG) 誘導表現病毒鞘蛋白 (Chen *et al*. 2002)。取 15 μL MCMV 鞘蛋白表現蛋白及 MCMV 感染病組織、健康組織及未轉型之 Rosetta *E. coli* 細胞於 150 V 進行十二烷基硫酸鈉聚丙烯醯胺凝膠電泳 (sodium dodecyl sulfate polyacrylamide gel electrophoresis; SDS-PAGE) 分析約 80 min 後，以 Coomassie Brilliant Blue 染色觀察結果。為確認 MCMV 鞘蛋白大小，且分析其有無會造成偽陰性蛋白混雜其中，再將未染色之 SDS-PAGE 與外購之 MCMV 免疫球蛋白 G (immunoglobulin G; IgG) 進行西方墨點轉漬法確認。後續將具 MCMV 鞘蛋白表現載體之 Rosetta *E. coli* 大量培養後，重複上述步驟取得大量表現之 MCMV 鞘蛋白，測量 A_{280nm} 吸光值並換算得到 1 mg mL^{-1} 濃度之蛋白質濃縮液。將獲得之濃縮 MCMV 鞘蛋白溶液，委託全盟生技公司免疫注射白兔並收集其抗血清。

間接法酵素連結免疫分析 (indirect enzyme-linked immunosorbent assay; indirect ELISA) 及種子群體測試

運用上述 MCMV 鞘蛋白之表現蛋白製備之抗血清，將抗血清依循 Clark &Adams (1977) 發表之方法純化 IgG 後，以專一性對應 MCMV 及外購之 MCMV IgG 進行 indirect ELISA 分析，所採用之 indirect ELISA 實驗步驟如前人所述 (Clark & Adams 1977; Lommel *et al*. 1982)；自製之 SCMV 抗血清 (Deng & Huang 1986)，以同樣方法純化 IgG 後進行 indirect ELISA 分析。

為檢測農民所使用種子是否有帶毒，採用 Chiang *et al*. (2007) 所發表之種子群體測試方法，將每包種子混勻後分為 1、3、5、10 粒種子各取樣 10 個樣本，100 粒種子取樣 5 個樣本，並置於研磨袋以榔頭敲碎等比例 (每粒種子加入 1 mL 清水) 研磨，並將之混勻後進行 indirect ELISA 分析。檢測結果依照 “Seed health” 方程式輸入 R 軟體 (R Core Team 2013) 後，可得出 MCMV 的種子帶毒率及信心範圍。

dsRNA 萃取及病毒全長序列選殖及分析

萃取 MCMV dsRNA 步驟修改自 (Valverde *et al*. 1986)，首先將 15 g MCMV 感染之玉米葉片凍於 -80℃冷凍櫃後取出，並於預冷之研缽配合液態氮磨碎成粉末，將磨碎病組織粉末倒入含 dsRNA 萃取緩衝液 (包含 45 mL 2× STE 緩衝

液 [0.1 M NaCl、0.02 M Tris-HCl (pH7.5)、0.01 M EDTA]、20 mL 10 % SDS、0.1 mL NH_4OH、0.8 mL 預冷之 4 % 膨潤土、1 mL 2-β-mercaptoethanol) 的離心管內。手搖 3−5 min 後，加入 25 mL 飽和苯酚 (pH 6.8) 至離心管內。手搖 3−5 min 後，再加入 25 mL 氯仿，之後置於混合器上室溫搖晃 45 min。之後以 8,000× *g* 離心 15 min，取上清液置入新離心管內，以 1× STE 緩衝液稀釋至 100 mL，並加入 100% 酒精直至酒精濃度為 17%，再加入 2 g CF-11 纖維素粉於離心管內。於混合器上常溫搖晃 45 min，之後將此纖維素混合溶液緩慢倒入管柱內，等 CF-11 纖維素粉沉澱後，將溶液析出。再沿管壁緩慢加入含 16.5% 酒精之 STE 緩衝液，亦等 CF-11 纖維素粉沉澱後，將溶液析出。當管柱內溶液到達纖維素粉液面時，加入 10 mL 1× STE 緩衝液，並以 30 mL 離心管收集析出液。將此析出液加入 20−25 mL 100 % 酒精及 0.1× 體積之 3 M NaOAC (pH 5.2) 後混勻，置於 -80℃ 1 h，再以 12,000× *g* 離心 30 min 後，加入 200−400 μL 的 1× STE 緩衝液，將沉澱物重新懸浮。之後以 10,000× *g* 離心 5 min，以去除纖維素粉，收集上清液並加入 2.5× 體積 100% 酒精及 0.1× 體積之 3 M NaOAC (pH 5.2) 混勻，置於 -80℃ 2 h，之後以 12,000× *g* 於 4℃條件下離心 15 min；為去除鹽類，再加入 2.5× 體積之 80% 酒精，並以 6,000× *g* 離心 3 min。將上清液去除並留下沉澱物後，置於 60℃烘箱烘乾，最後以 20 μL DEPC 處理的水回溶。

將獲得之 dsRNA 以 poly(A) tailing kit (Thermo Fisher Scientific Inc., Waltham, MA, USA) 進行多聚腺苷酸化 (polyadenylation)，方法依照其說明書進行。將適量的 dsRNA 與 DEPC 處理的水混合至 13.5 μL，並於 100℃乾浴 5 min 後，置於冰上 5 min，以將 dsRNA 變性 (denature)。之後加入 5× 緩衝液 4 μL、poly(A) polymerase 1 μL 及 25 mM ATP 2 μL 於 dsRNA 溶液中，至總體積 20 μL，混勻後置於 37℃條件下 30 min。將 dsRNA 正反股之 3' 端各添加 poly(A) tail，最後置於 65℃，10 min 後終止反應。取 5 μL 帶有 poly(A) tail 的 dsRNA，並分別加入 XhoI oligod (T) V 引子 1 μL 及 10 mM dNTP 1 μL 後補水至 12 μL，置於 65℃條件下 5 min 後置於冰上。再分別加入 5× FS 緩衝液 4 μL、0.1 M DTT 1 μL 及 RNase OUT 1 μL，於 42℃條件下處理 2 min 後，加入 1 μL SuperScriptII 反轉錄酵素，並於 42℃作用 50 min 後，置於 70℃條件下 15 min 終止反應。獲得之 cDNA 產物，以依 MCMV 5 端序列設計引子 MCMV 5' RACEA 及利用已知 MCMV 鞘蛋白引子 MCMV-g3514F 分別與 XhoI oligod (T) V 引子進行 5' 端及 3' 端序列增幅，PCR 反應組成如下：2× Taq DNA Polymerase Master Mix RED 10 μM，正反股引子各 1 μL，cDNA 1–2 μL，補水至 20 μL。PCR 增幅條件為 94℃ 5 min 後進行 (94℃ 30 s, 50℃ 30 s, 72℃ 1 min) 35 個循環，72℃ 10 min 後靜置於 4℃；將 PCR 增幅產物以 1.5% 洋菜膠，在 0.5× TAE，50 V 條件下進行電泳，最後以 EtBr 染色 10 min 後，以清水退染。將預期大小產物切下後，以凝膠產物小量回收試劑組 (Gel Advanced Gel Extraction Miniprep, VioGene-Biotek Corp., New Taipei City, Taiwan) 進行回收，產物依循 T&A 選殖試劑組 (T&A™ Cloning Kit, Yeastern Biotech, New Taipei City, Taiwan) 操作流程進行接合 (ligation)，之後將接合產物依循操作流程轉入勝任細胞 (ECOS™ Competent Cells, E.coli DH5α strain, Yeastern Biotech, New Taipei City, Taiwan) 後，將菌液塗佈於 LB-agar (Amp100/IPTG/X-gal)，培養於 37℃隔夜。待菌落形成後，取出放置於 4℃隔夜，進行藍白篩選。為確認選殖菌落正確與否，將選殖菌落以 M13F/M13R 引子對進行菌落 PCR (Colony PCR) 增幅確認後，將菌落交由明欣生物科技定序。

生物資訊分析

以簡併式引子對增幅出產物經選殖解序後，以 NCBI 網站 (National Center for Biotechnology information, http://www.ncbi.nlm.nih.gov/) 上的 Blastn 線上軟體進行比對。針對 MCMV 鞘蛋白序列及全長序列以套裝軟體 Lasergene 13 (DNAStar, Inc., Madison, WI, USA)，進行拼接，並將其核酸序列分別以 Clustal Ω 比對方法 (Sievers *et al*. 2011) 進行多重序列比對 (multiple sequence alignment)。將比對後的核酸序列，再於 MEGA 7.0 軟體 (Kumar *et al*. 2016) 以 neigh-

bor-joining 的方法建構 phylogenetic tree。其樹形分支的可信度，經由拔靴 (bootstrap) 方法進行 1,000 次重覆而決定。

結果

病毒分離與簡併式聚合酶鏈鎖反應及血清檢測比對鑑定

2014 年台灣各地疑似病毒病危害玉米大發生，受害植株有褪綠、嵌紋、葉片黃化、植株枯萎情形甚至植株嚴重矮化 (圖 1A、1B)，將病葉透光觀察可見明顯且平行於葉脈之褪綠條斑，甚至造成葉片嚴重黃化 (圖 1C、1D)。將由雲林縣虎尾鎮採樣之疑似病毒病為害玉米葉片汁液機械摩擦接種於甜玉米 (*Zea mays* var. *rugosa* cv. 'Honey-236')，五週後可見新長出葉片有明顯褪綠、斑駁病徵 (圖 1E、1F)。由於無合適之單斑寄主，因此以系列稀釋接種法分離病毒，將接種後具病徵之玉米植株葉片以 2× 系列稀釋至 20,000× 分別接種於甜玉米 'Honey-236'，每稀釋濃度各接種 10 棵甜玉米 'Honey-236'，接種後發現稀釋終點為 200×。2000× 則無法順利接種，因此以 500× 稀釋倍率接種 3 次甜玉米 'Honey-236' 後獲得一純系病毒 (分離株：NFU2)。以自製之 SCMV 抗血清 (Deng 1985) 進行檢測呈現陰性反應，後以自行設計針對 *Tenuivirus* 屬病

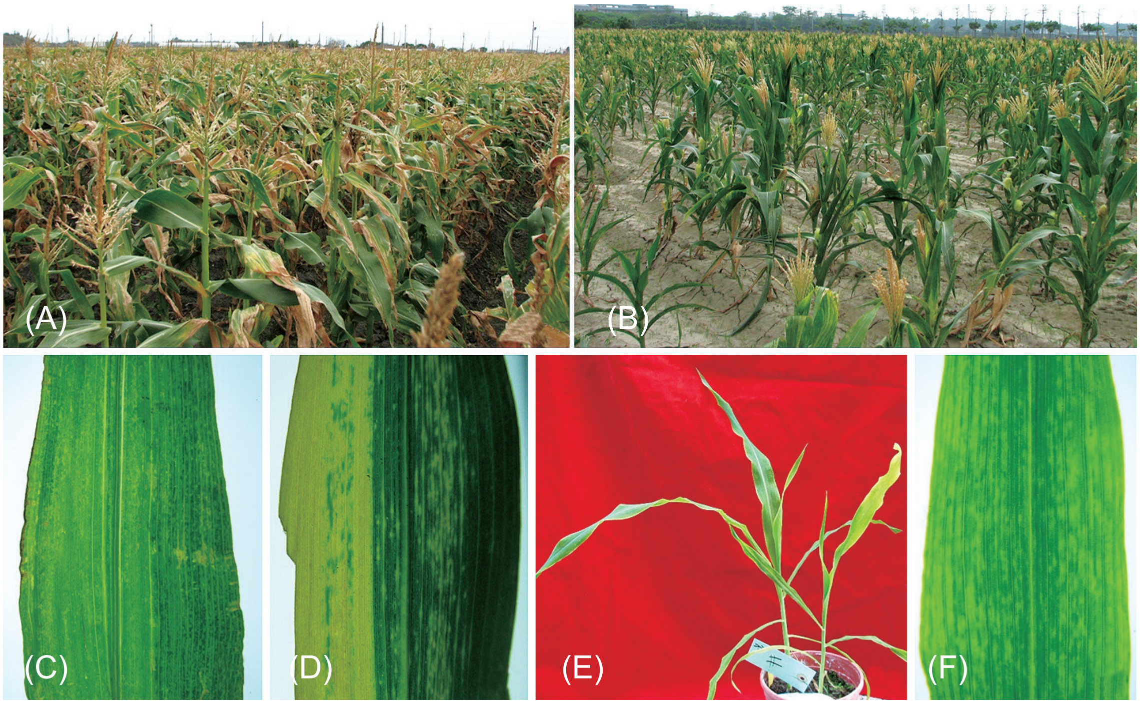


圖 1. (A) 玉米褪綠斑駁病毒於田間造成之褪綠、黃化及枯萎病徵；(B) 玉米褪綠斑駁病毒與甘蔗嵌紋病毒於田間大面積複合感染使植株嚴重矮化、簇生化、黃化且植株死亡情形；(C) 玉米褪綠斑駁病毒單獨感染葉片呈現典型褪綠斑駁與葉脈平行的條狀病斑；(D) 玉米褪綠斑駁病毒與甘蔗嵌紋病毒複合感染葉片病斑會癒合造成更嚴重的黃化病徵；(E) 病組織汁液機械摩擦接種於甜玉米 'Honey-236' 5 wk 後可見葉片呈現褪綠、黃化病徵；(F) 接種感染的玉米植株葉片組織有嵌紋病徵。

Fig. 1. (A) Field symptoms of severe mottle, chlorosis and necrosis caused by *Maize chlorotic mottle virus* (MCMV) infection; (B) Plants with severe stunting, rosetting, yellowing and even death caused by MCMV coinfection with *Sugarcane mosaic virus* (SCMV) in the field; (C) Leaf with chlorotic mottle streaks parallel to leaf veins, typical of MCMV simplex infection; (D) Streaks coalesce to create severe yellowing symptom caused by MCMV coinfected with SCMV; (E) Chlorotic mottle symptom appeared after 5 wk post inoculation with MCMV on sweet corn cv. 'Honey-236'; and (F) Infected leaf tissue with clear mottle symptoms caused by MCMV inoculation.

表 **1.** 本研究中所使用之引子對。

Table 1. List of primers in this study.

Primer pair	Sequence (5'−3')	Target or purpose	Product size (bp)	Ref.
Hrp5 Pot1	F-ATGATHGARKCNTGGGG R-GACTGGATCCATTBTCDATRCACCA	*Potyvirus* genus universal primers	750	Colinet & Kummert (1993); Pappu *et al.* (1998)
Tenui-DF1 Tenui-DR1	F-AAGAARAADWKAGDCCGTA R-ACACAAAGTCCTGGGTAWAA	*Tenuivirus* genus universal primers	1,400−1,800	This study
Potex2RC Potex5	F-TCAGTRTTDGCRTCRAARGT R-CAYCARCARGCMAARGAYGA	*Potexvirus* genus universal primers	750	van der Vlugt & Brenedsen (2002)
MCMVg3514F MCMVg4014R	F-GGGAACAACCTGCTCCA R-GGACACGGAGTACGAGA	MCMV coat protein specific primer which can be used to detect MCMV in vectors, seeds and plants	500	This study
NdeI-MCMVCP-F MCMVCP-SalI-R	F-ATCATATGGCGGCAAGTAGCC R-ATGTCGACTCAATGATTTGCCAG	MCMV coat protein expression vector construction	820	This study
MCMV-CPF MCMV-CPR	F-TGGGAATTCCAGCCAGATTA R-TGAGTTCAGAAACCCTCGTG	MCMV full coat protein sequence amplification	2,000	This study
MCMV-g3514F XholOligod(T)V	F-GGGAACAACCTGCTCCA R-CTCGAGTTTTTTTTTTTTTTTTTTV	MCMV 3' region sequence amplification	947	This study
XholOligod(T)V MCMV5'RACEA	F-CTCGAGTTTTTTTTTTTTTTTTTTV R-GGTGTCTGGTACACCCAACC	MCMV 5' region sequence amplification	703	This study

毒的簡併式引子對 Tenui-DF1/Teuni-DR1、*Potexvirus* 屬病毒簡併式引子對 Potex1RC/Potex5 及 *Potyvirus* 屬病毒簡併式引子對 Hrp5/Pot1 (表 1)，分別對採樣的樣本抽取之全量 RNA 進行 RT-PCR 增幅偵測可能的病毒種類。RT-PCR 增幅結果顯示，僅能於利用 *Tenuivirus* 屬病毒簡併式引子對偵測可得預期大小約 1.4−1.8 kb 之條帶 (圖 2)，*Potexvirus* 屬病毒及 *Potyvirus* 屬引子，

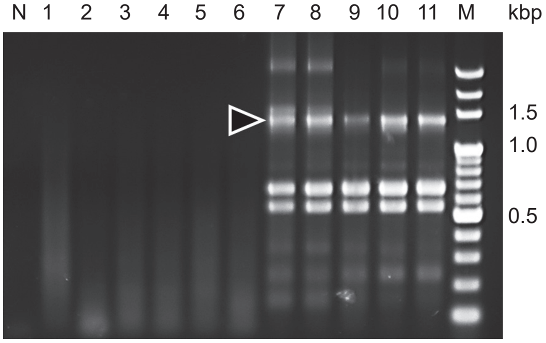


圖 2. 利用 *Tenuivirus* 屬病毒簡併式引子對偵測採集自雲林縣疑似病毒病為害玉米樣本之反轉錄聚合酶連鎖反應實驗，符合預期約 1.4 kb 大小反轉錄聚合酶鏈鎖反應 (reverse transcriptase polymerase chain reaction; RT-PCR) 產物如箭頭所示。行 N：無核酸模板負對照 [diethyl pyrocarbonate (DEPC) 處理水]；行 1−11：疑似病毒病感染玉米樣本 RNA；行 M：核酸分子標準液 (Bio-100™ Mass DNA Ladder)。

Fig. 2. Detection of virus like symptom of maize samples from Yunlin County by reverse transcription polymerase chain reaction (RT-PCR) using *Tenuivirus* genus degenerate primers. The RT-PCR products with predicted size (1.4 kb) identified by 1.5% agarose gel electrophoresis are indicated by arrow. Lane N: No template control [diethyl pyrocarbonate (DEPC) treated water]; Lanes 1−11: Suspected virus infected maize sample RNA; and Lane M: Bio-100™ Mass DNA Ladder.

則未測得預期大小之條帶。將符合預期大小約 1.4 kb產物，經選殖解序後可分別得到一段1,367 bp 及一段 1,488 bp 的 cDNA 片段 (圖 3A)，兩片段具 101 bp 的重疊序列，可將兩片段組合為一個 2,703 bp 的單一序列重疊群 (contig) (圖 3B)。將序列上傳 NCBI 進行比對，結果顯示此序列與中國於 2012 年發表之 MCMV Yunnan3 分離株序列 (Acc. No. JQ982469) 最相近，核酸序列相同度達 99%，且此序列包含 MCMV 部分 5' 端未轉譯區序列、P32 蛋白及 RNA 依賴性 RNA 聚合酶 (RNA dependent RNA polymerase; RdRp) 完整序列。另外，與非洲肯亞及盧安達於 2012 及 2013 年發表之 MCMV 分離株核酸序列相似亦達 99%，而與美國於 2007 年發表之 MCMV 分離株 "Nebraska" 相同度達 97%。1989 年於美國堪薩斯州發現之 MCMV 分離株 KS1 核酸相同度亦有 96% (表 2)，證實此一新發生玉米病毒為近年來於亞非地區大發生之 MCMV。

玉米褪綠斑駁病毒 NFU2 分離株全長度基因體選殖及分析

為分析此一台灣新發生病毒之來源、針對病毒鞘蛋白序列開發檢測引子及製備表現載體，後續將 MCMV NFU2 分離株之全長度基因體序列進行解序。首先，針對 MCMV 病毒之鞘蛋白序列進行解序，依據已知之 MCMV NFU2 分離株之 RdRp 序列及 GenBank 上 MCMV 病毒 3' 端 UTR 序列設計引子 MCMV-CPF/MC-

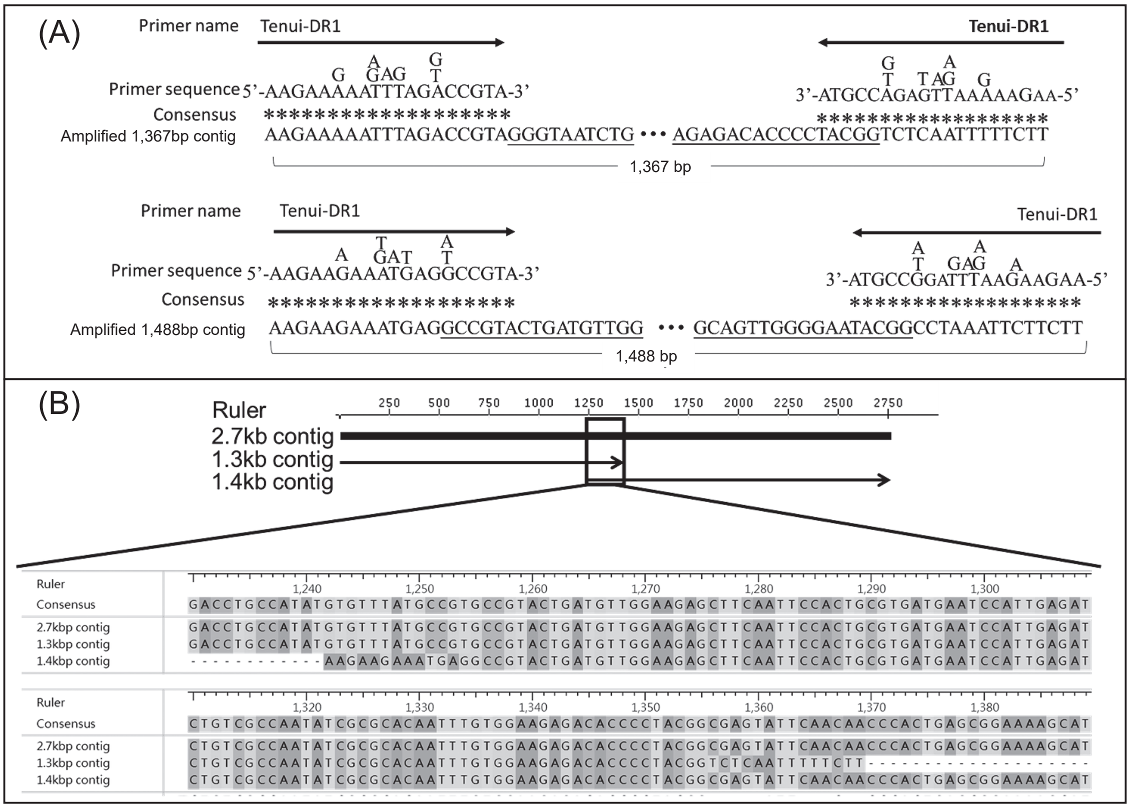


圖 3.　(A) 將由 *Tenuivirus* 屬病毒引子對 (TenuiDF1/TenuiDR1) 增幅並選殖之序列與該簡併式引子對比對；(B) 兩組增幅單一序列重疊群 (contig) 間具有 101 bp 的重疊序列，可組合成一個 2.7 kbp 單一序列重疊群。

Fig. 3.　Alignment of two cloned sequences which are amplified from using TenuiDF1/TenuiDR1 primer pairs with its own primer pairs. Degenerate primer pairs were presented on the top of each alignment. The arrows indicate the direction of 5' to 3' in each primer. The asterisks indicate the conserved nucleotides among all aligned DNA sequences. Underlined sequences are identical to *Maize chlorotic mottle virus* (MCMV) sequences. (B) These two amplified contig could combine into a 2.7 kbp contig with 101 bp overlapping sequence.

表 2. 將 *Maize chlorotic mottle virus* (MCMV)-NFU2 分離株之聚合酶鏈鎖反應產物序列拼接後之單一重疊群與其他國家之 MCMV 序列相同度比較。

Table 2. Comparison of nucleotide identities of 2.7 kbp assembled contig from degenerated reverse transcriptase polymerase chain reaction (RT-PCR) products of *Maize chlorotic mottle virus* (MCMV)-NFU2 with isolates of MCMV from other countries.

MCMV isolate (accession No.)	Country	Nucleotide identity (%)	Submitted year
Yunnan3 (JQ982469)	China	99	2012
Sichuan (JQ982470)	China	99	2012
Yunnan2 (JQ982468)	China	99	2012
Kenya (JX286709)	Kenya	99	2012
R4 (KF744396)	Rwanda	99	2013
R1 (KF744395)	Rwanda	99	2013
Nebraska (EU358605)	USA	97	2007
KS1 (X14736)	USA	96	1989

MV-CPR，經 RT-PCR 增幅擴大後，可獲得一 2 kb 產物。經選殖解序後比對，確認獲得 MCMV 病毒完整鞘蛋白核酸序列，並經親緣分析後顯示各 MCMV 分離株之全鞘蛋白核酸序列可區分為 2 個族群 (圖 4)，分別為美國分離株群及近年來於亞非地區發生之分離株群。另外，由於 MCMV 屬於番茄叢矮病毒科 (*Tombusviridae*) 玉米褪綠斑駁病毒屬 (*Machlomovirus*)，該屬病

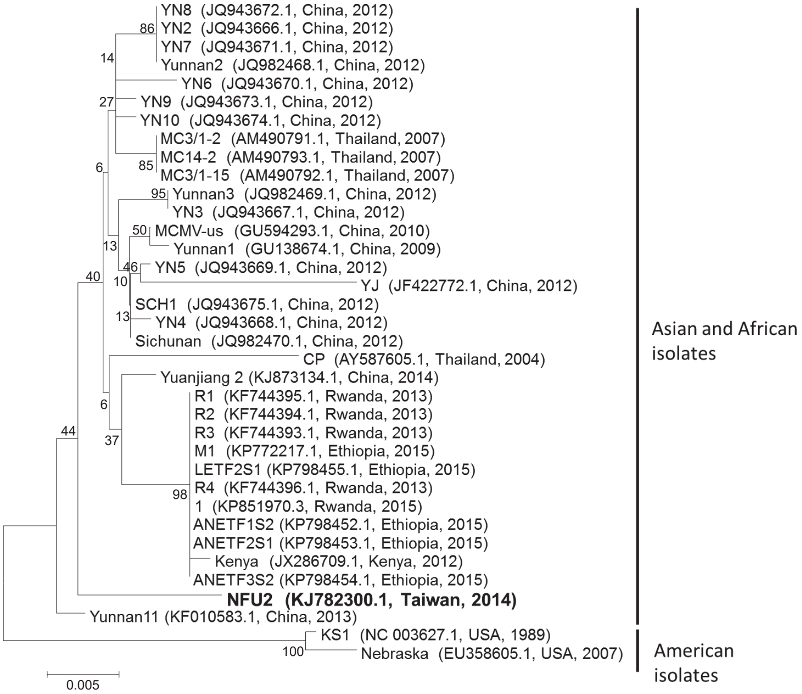


圖 4. 玉米褪綠斑駁病毒 NFU2 分離株鞘蛋白核酸序列以 MEGA 7.0 進行親緣關係分析之樹狀圖。

Fig. 4. The phylogenetic tree of coat protein nucleotide sequences of *Maize chlorotic mottle virus* (MCMV) NFU2 isolate and other MCMV isolates available in GenBank. The neighbor-joining tree was constructed with MEGA 7.0 and bootstrapped with 1,000 replicates. Scale bar indicates 0.005 changes per nucleic acid. The accession number of coat protein nucleotide sequence, isolation country and first GenBank submission year of each MCMV isolates are indicated following the isolate name.

毒基因體組成無 5’ 端 cap 及 3’ 端 poly(A) tail，因此先萃取本病毒之 dsRNA，之後以 poly(A) tailing kit 將病毒 dsRNA 兩端分別添加 poly(A) tail，再分別依據已知之 MCMV5’ 端序列設計引子 MCMV5’RACEA 及利用已知 MCMV 鞘蛋白引子 MCMV-g3514F 分別與 XhoI oligod (T) V 引子進行 5’ 端及 3’ 端序列增幅。經選殖解序後比對，確認獲得 MCMV 病毒 5’ 端及 3’ 端序列 (結果未出示)。將已經獲得之 MCMV NFU2 分離株 5’ 端 UTR、P32 蛋白、RdRp、P31 蛋白、鞘蛋白及 3’UTR 序列拼接後，可得 MCMV NFU2 分離株完整序列，全長為 4,436 nt。將 NFU2 分離株序列各功能蛋白及 5’ 端及 3’ 端 UTR 序列，與已完整解序之 MCMV 分離株核酸序列進行比對 (表 3)，結果顯示與 MCMV “NFU2” 分離株 5’ 端 UTR 最相近者 (98.5%) 為 Yunnan3 及 M1 分離株，差異度最大者 (94.1%) 為 Nebraska 及 KS1 分離株；P32 蛋白最相近者 (98.9%) 為 Yunnan3 及 M1 分離株，差異度最大者 (97.5%) 為 Nebraka 分離株；RdRp 蛋白最相近者 (98.9%) 為 Yunnan3 分離株，差異度最大者 (96.4%) 為 KS1 分離株；P31 蛋白最相近者 (99.3%) 為 Yunnan3 分離株，差異度最大者 (97.1%) 為 Nebraska 分離株；鞘蛋白相近者 (98.3%) 為 M1、Yunnan 及 R1 分離株，差異度最大者 (96.3%) 為 Nebraska 分離株；sgRNA2 最相近者 (99.4%) 為 Yunnan3 分離株，差異度最大者為 R1 分離株，因其缺乏 3’ 端序列，其相同度僅有 86.6%；將 MCMV NFU2 分離株全長度序列與於 GenBank 登錄之 MCMV 全長度基因體序列進行親緣分析，由圖 5 可知 MCMV 可區分為東非分離株群、台灣分離株、中國分離株群及美國分離株群，2012 年後發生之 MCMV 分離株序列相同度皆為 99%，並且從樹形可區分出東非分離株、台灣分離株及中國分離株為同一群，而美國分離株則為另一分群，此一結果與全鞘蛋白核酸序列分析相近。

玉米褪綠斑駁病毒鞘蛋白表現載體製備與血清檢測應用

基於已經解序之 MCMV NFU2 分離株鞘蛋白核酸序列，可以將該鞘蛋白序列以 NdeI-MCMVCP-F/MCMVCP-SalI-R 引子對增幅後構築於 pET28b (+) 表現載體上，並轉型至 *E. coli* strain Rosetta (DE3) 大腸桿菌細胞中，並重新抽取 MCMV-NFU2 CP 表現載體經 PCR 增幅選殖確認序列正確，之後以 IPTG 誘導產生 MCMV-NFU2 CP 表現蛋白因帶有部分表現載體序列，產物大小約 28 kDa，略大於 MCMV 感染玉米葉片之 CP 大小 (約 25 kDa) (圖 6A)。西方轉漬法分析結果顯示，MCMV-NFU2 表現蛋白可與購自 AC Diagnostics 之 MCMV 抗血清有專一性反應 (圖 6B)。將此表現蛋白經白兔免疫注射後所製備之抗血清用於 ELISA 試驗檢測田間

表 3. *Maize chlorotic mottle virus* (MCMV)-NFU2 分離株與其他 MCMV 分離株之 5’ 端 UTR、P32 蛋白、RdRp、P31 蛋白、鞘蛋白及 sgRNA2 核酸序列相同度比較。

Table 3. Comparison of nucleotide identities of 5’UTR, P32, RdRp, P31 and subgenomic RNA 2 of *Maize chlorotic mottle virus* (MCMV)-NFU2 with isolates of MCMV from other countries.

		MCMV genome sequence identity (%)					
Country	Isolate	5’UTR	P32	RdRp	P31	CP	sgRNA2
Taiwan	NFU2	100.0	100.0	100.0	100.0	100.0	100.0
Ethiopia	M1	98.5	98.9	98.8	98.9	98.3	92.6[z]
China	Yunnan3	98.5	98.9	98.9	99.3	98.2	99.4
China	Yunnan	97.1	98.6	98.8	98.3	98.3	96.7
Kenya	Kenya	96.3	98.7	98.8	98.8	98.2	99.7
Rwanda	R1	94.1	98.6	98.8	98.9	98.3	86.6
USA	Nebraska	94.1	97.5	96.7	97.1	96.3	98.2
USA	KS1	94.1	98.6	96.4	97.6	96.6	98.2

[z] Ethiopian isolate M1 and Rwandian isolate R1 have lack of partial sgRNA2 sequence at the end.

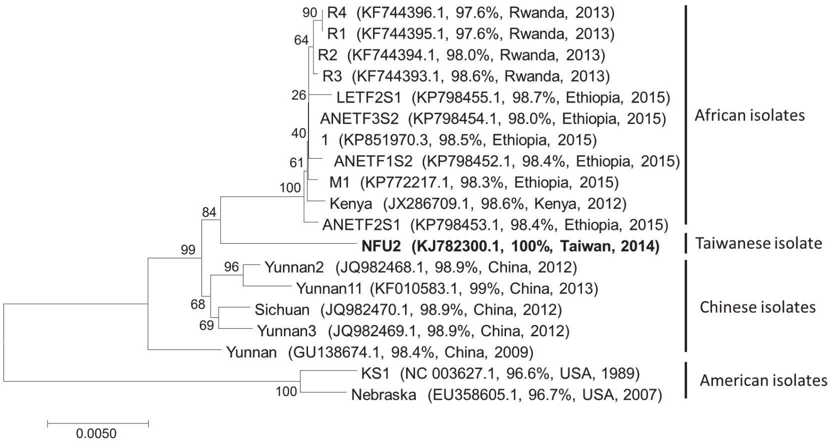


圖 5. 玉米褪綠斑駁病毒基因體 NFU2 分離株全長度核酸序列以 MEGA 7.0 進行親緣關係分析之樹狀圖。

Fig. 5. The phylogenetic tree of complete genome sequences of *Maize chlorotic mottle virus* (MCMV) NFU2 isolate and other MCMV isolates available in GenBank. The neighbor-joining tree was constructed with MEGA 7.0 and bootstrapped with 1,000 replicates. Scale bar indicate 0.005 changes per nucleotide. The accession number of complete nucleotide sequence, sequence identity, isolation country and first GenBank submission year of each MCMV isolates are indicated following the isolate name.

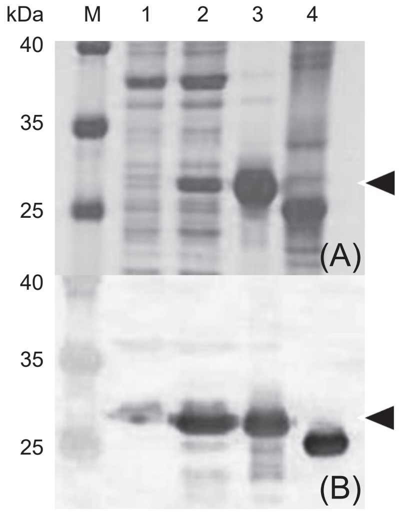


圖 6. 轉型細菌經誘導後大量表現 *Maize chlorotic mottle virus* (MCMV)-NFU2 鞘蛋白之蛋白質電泳及西方轉漬分析。(A) 十二烷基硫酸鈉聚丙烯醯胺凝膠電泳 (sodium dodecyl sulfate polyacrylamide gel electrophoresis; SDS-PAGE) 分析；(B) 西方轉漬法分析。

Fig. 6. Expression of *Maize chlorotic mottle virus* (MCMV)-NFU2 coat protein in *E. coli* strain Rosetta (DE3) demonstrated after protein induction by isopropyl β-D-thiogalactoside (IPTG). (A) Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) with coomassie blue staining of the 28 KDa bacterial expressed recombinant MCMV-NFU2 coat protein which indicated by arrow; and (B) Western blot assay of the recombinant MCMV-NFU2 coat protein was reacted with the 500× diluted antiserum against MCMV which purchased from AC Diagnostics, Inc. Lane M, protein marker; Lane 1, pET28b (+) without insert; Lane 2, pET28b (+) with MCMV-NFU2 CP insert; Lane 3, purified bacterial expressed recombinant MCMV-NFU2 coat protein; and Lane 4, MCMV-infected maize leaf. Sample of each number of lanes were the same in SDS-PAGE and western blotting results.

樣本，結果顯示自製之 MCMV 抗血清可穩定偵測出感染 MCMV 之玉米樣本 (表 4)，總共採樣 11 個田間疑似 MCMV 感染樣本，皆可順利測得 MCMV 陽性反應，而健康對照反應背景值低。

分子檢測引子對開發及應用

由於 MCMV 為一可藉由薊馬媒介傳毒之植物病毒，為檢測薊馬是否可能為台灣 MCMV 傳毒之媒介昆蟲，本研究利用針對不同 MCMV 分離株鞘蛋白保守序列設計一專一性引子對 MCMV-g3514F/MCMV-g4014R，並用以檢測 MCMV 大發生之田間捕獲薊馬。經鑑定後，該薊馬為玉米薊馬，並以專一性引子對檢測，結果顯示此引子對可用於檢測採集之單隻玉米薊馬體內帶毒與否 (圖 7)。此外，經測試此專一性引子對，可應用於檢測葉片是否感染 MCMV，

表 4. 自製與商用抗體用於酵素免疫分析法 (enzyme-linked immunosorbent assay; ELISA) 檢測玉米樣本感染 *Maize chlorotic mottle virus* (MCMV) 之效果比較。

Table 4. Comparative results of enzyme-linked immunosorbent assay (ELISA) using homemade and commercialized antibodies to detect *Maize chlorotic mottle virus* (MCMV) on maize.

Maize sample	MCMV antibody	
	Homemade[z]	AC Diagnostics[y]
1	1.92[x]	2.14[x]
2	2.59	2.28
3	0.19	0.75
4	3.19	2.22
5	1.78	2.39
6	0.21	0.98
7	1.94	1.60
8	0.59	1.40
9	0.38	1.46
10	0.46	0.97
11	0.56	2.28
Diseased positive control	3.29	3.03
Healthy control threshold	0.13	0.11

[z] Purified immunoglobulin G (1 mg mL^{-1}) of antiserum against MCMV-NFU2 with 250× dilution.
[y] Immunoglobulin G against MCMV purchased from AC Diagnostics Inc. with suggested 1000× dilution.
[x] Enzyme-linked immunosorbent assay (ELISA) values (Absorbance at 405 nm, A_{405nm}).

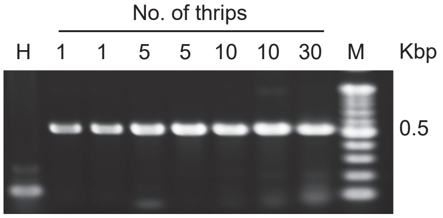


圖 7. 應用 *Maize chlorotic mottle virus* (MCMV) 專一性引子對檢測田間玉米薊馬帶毒情形。

Fig. 7. Agarose gel electrophoresis analysis of amplified *Maize chlorotic mottle virus* (MCMV) cDNA products from field collected maize thrips by reverse transcriptase polymerase chain reaction (RT-PCR) with MCMV specific primers MCMV-g3514F/MCMV-g4014R. Numbers of maize thrips were indicated above each lane: Lane H, Healthy maize leaf was used as negative control; and Lane M, Bio-100TM Mass DNA Ladder.

種子是否有帶毒以及其他可能潛在媒介昆蟲是否帶毒等 MCMV 病毒檢測實驗 (結果未出示)。

玉米褪綠斑駁病毒病害發生調查

玉米褪綠斑駁病毒為近年來新發生且嚴重危害玉米之病毒，由於其傳播特性關係，於台灣田間有大發生情形，於雲林縣、嘉義縣市、台南市、高雄縣、苗栗縣、台中市、彰化縣、花蓮縣、台東縣等地區採樣疑似病毒病危害食用玉米樣本共 306 個，其中 MCMV 罹病率為 79.7% (共 244 個樣本呈現 MCMV 陽性反應)，MCMV 與 SCMV 複合感染比率為 31.7% (共 97 個樣本呈現 MCMV 及 SCMV 陽性反應) (表 5)。其中，各地區 MCMV 罹病率介於 68.4−87.1% 之間，MCMV 及 SCMV 複合感染比率則變化較大，雲林縣部分為 0%，高雄縣燕巢區則為 71%；分析受 MCMV 感染玉米種類結果顯示如表 6，市面上常見之食用商業品種，如「金蜜」、「真滋蜜」、「彩珍」、「夏強」、「夏珍」、「白龍王」、「雙發」、‘Devotion’、「台南 22 號」及「玉美珍」等品種 MCMV 罹病率皆達 80% 以上，這些玉米種類包括雙色甜玉米、黃色甜玉米、白色甜玉米、白玉米及糯玉米等玉米品種，而青割玉米及「明豐 3 號」飼料玉米各調查 22 個

表 5. 2014 年至 2015 年間台灣食用玉米發生 *Maize chlorotic mottle virus* (MCMV) 及 *Sugarcane mosaic virus* (SCMV) 調查結果。

Table 5. Occurrence of *Maize chlorotic mottle virus* (MCMV) and *Sugarcane mosaic virus* (SCMV) on symptomatic maize plants collected in Taiwan from 2014 to 2015.

Location	No. of plants assayed	Number and percentage of maize infected with MCMV[z]	Number and percentage of maize coinfected with MCMV and SCMV[y]
Yunlin County	86	74 (86.0%)	0 (0%)
Chiayi County	60	49 (81.6%)	14 (23.3%)
Yanchao Dist., Kaohsiung City	62	54 (87.1%)	44 (71.0%)
Other places	98	67 (68.4%)	39 (39.8%)
Total	306	244 (79.7%)	97 (31.7%)

[z] Enzyme-linked immunosorbent assay (ELISA) tests with antiserum against *Maize chlorotic mottle virus* (MCMV) were performed.
[y] ELISA tests with antiserum against MCMV and *Sugarcane mosaic virus* (SCMV) were performed.

表 6. 2014 年至 2015 年間台灣不同品種玉米之 *Maize chlorotic mottle* (MCMV) 感染率調查結果。

Table 6. Incidence of *Maize chlorotic mottle* (MCMV) in different maize cultivars in Taiwan from 2014 to 2015.

Maize cultivar	Type	No. of plant assayed	Number and percentage of maize infected with MCMV (Percentage)[z]
‘Chen-tzu-mi’「真滋蜜」	Bicolor sweet corn	15	15 (100%)
‘SC2015’「雙發」	Bicolor sweet corn	55	49 (89.1%)
‘Sweet Jean’「彩珍」	Bicolor sweet corn	16	16 (100%)
‘Devotion’	White sweet corn	9	9 (100%)
‘White Dragon King’「白龍王」	White sweet corn	42	36 (85.7%)
‘SC-34’「金蜜」	Yellow sweet corn	15	15 (100%)
‘Chia-Chiang’「夏強」	Yellow sweet corn	5	4 (80.0%)
‘Bright Jean’「華珍」	Yellow sweet corn	25	15 (60.0%)
‘Tainan No. 22’「台南 22 號」	White corn	30	25 (83.3%)
‘White pearl’「玉美珍」	Waxy corn	73	62 (84.9%)
Unknown	Forage corn	22	7 (31.8%)
‘Ming-Feng No. 3’「明豐 3 號」	Feed corn	117	37 (31.6%)

[z] Enzyme-linked immunosorbent assay (ELISA) tests with antiserum against *Maize chlorotic mottle* (MCMV) were performed.

及 117 個樣本，MCMV 罹病率分別為 31.8% 及 31.6%。所有甜玉米品種中，「華珍」玉米病毒罹病率較低，但也達到 60%。

討論

在台灣玉米感染植物病毒的鑑定報告於 2014 年以前僅有 MDMV-B (現為 SCMV，*Potyvirus* 屬病毒) 及 MSpV (*Tenuivirus* 屬病毒) 兩種病毒，故於 2014 年春天於雲林縣虎尾鎮採集之嚴重黃化、嵌紋且矮化之玉米植株，經以自製之 SCMV 抗血清進行 ELISA 檢測未得陽性反應，遂以已經存在台灣之兩屬玉米病毒簡併式引子對進行檢測。檢測結果僅自行設計之 *Tenuivirus* 屬病毒簡併式引子對可針對部分樣品增幅出預期之條帶大小，且經選殖解序後分別獲得兩組大小約 1.4 kb，分別位於 MCMV 的 RdRp 5' 端及 3' 端，且兩段序列可進行拼裝後組合成一單一序列重疊群，並經比對確認為 MCMV。此一非預期之解序結果，可能係由於進行 degenerate RT-PCR 時黏合溫度 (annealing temperature) 較低所致，且運用該 *Tenuivirus* 屬病毒引子對針對 MSpV 進行增幅時亦會發生可分別增幅 RNA-2 及 RNA-3 (未發表結果)，該引子對序列或具特殊性，可做為跨病毒屬且可針對同一病毒不同片段進行增幅，此須進一步研究才可瞭解。

Adams *et al*. (2013)、Adams *et al*. (2014) 和 Mahuku *et al*. (2015b) 發表的結果指出，MCMV 可分為 3 個族群，分別為美國分離株、中國分離株及東非分離株。將全解序之 MCMV NFU2 分離株親源分析，結果依照來源地顯示共可分群為美國分離株、中國分離株、東非分離株及台灣分離株，此分群結果顯示台灣分離株與東非分離株在演化關係上較為接近。分析 5' 端 UTR、P32 蛋白、RdRp、P31 蛋白、鞘蛋白及 sgRNA2 等核酸序列，顯示 MCMV NFU2 分離株與其他各國全解序 MCMV 分離株在 5' 端 UTR 及鞘蛋白序列歧異度較高。若進一步將鞘蛋白序列進行親源分析，MCMV NFU2 分離株鞘蛋白序列與東非分離株及泰國於 2004 年登錄之 CP 分離株屬同一分群，雖然泰國於 2007 年所分離的 MC3/1–15 等分離株較接近中國分離株，但整體而言該親源樹除美國分離株外，其他分枝的 MCMV 分離株核酸變異度較低，且在大分枝樹形的信賴度小於 40，顯示東非分離株、台灣分離株、中國分離株及泰國分離株起源可能為同一來源，此一分析結果與 Wu *et al*. (2013) 分析結果相近。而亞非國家中又以泰國於 1983 年最先報導 (Klinkong & Sutabutra 1982)，之後至 2004 年才有首筆分析 MCMV 鞘蛋白紀錄，藉由親源分析合理推測近年來爆發之 MCMV 分離株可能由泰國分離株分化而來；且後續分析實驗室 2013 年採樣分離之玉米樣本即有 MCMV 感染之情形 (結果未出示)，因此台灣的 MCMV 分離株應早於 2013 年以前即由國外傳入台灣。

基於各分離株鞘蛋白相同度在 96% 以上，將 MCMV NFU2 分離株之鞘蛋白序列構築於表現載體並誘導大量表現，獲得之 MCMV NFU2 CP 表現蛋白可以穩定檢測 MCMV 田間樣本，有利後續田間生態及病害流行調查；MCMV 專一性引子對檢測證明單一玉米薊馬可以有效獲毒，後續進行傳毒試驗亦可成功，並且經調查玉米薊馬在田間條件合適時具有高密度 (未發表結果)，藉由專一性引子對的檢測可以分析媒介昆蟲的獲毒、傳毒、保毒等相關資料，未來將可提供相關防治策略的擬定。目前防檢局已經公告之賜諾特、納乃得及撲滅松等多種類型藥劑可供輪替使用，此外該引子對亦可應用於田間玉米樣本的檢測或是種子的檢測，可提供檢測時更靈敏的檢測工具。

MCMV 於台灣在 2014 年中南部地區大面積的發生危害，由於許多玉米栽培區幾乎同時間發生大面積黃化乾枯情形，許多田區幼苗期即有黃化斑駁情形，農民懷疑是否有種子帶毒情形。經將大面積發生的玉米田區農民使用所剩玉米籽粒共七個品種各千粒種子，以群體方式取樣後以 MCMV 抗血清進行檢測，結果顯示皆未測得種子帶有 MCMV 情形 (結果未出示)。研判若使用合格廠商提供之種子帶毒比率極低或無，此外在尚未清楚病原的情況下，錯誤的殺菌劑、殺蟲劑使用層出不窮，經確診為 MCMV 病毒感染後始能對症下藥。而經過調查，當時農民常用的各種甜玉米品種罹病率皆達 80% 以上，「華珍」品種則罹病率較低 (60%)，但其甜度、果皮厚度等性狀較差，若欲選擇「華珍」作

為栽培品種須將品質納入考慮；而同一時間田間調查 MCMV 感染青割玉米及硬質玉米的罹病率約 30% 左右，由於其栽培習慣較粗放，因此實際調查其植株上玉米薊馬密度仍偏高，但受 MCMV 感染植株比率較低，且病徵僅多為褪綠斑駁或輕微矮化、較無大面積黃化、枯死情形；分析台灣各地區 MCMV 及 MLN 發生情形，結果顯示雲林地區僅有 MCMV 發生，嘉義縣及其他玉米栽培區則為 23−39% 之間，高雄市燕巢區為單一有機栽培農場，在未積極管理媒介昆蟲下，顯示 MLN 罹病率可以達到 71%，在病害大發生狀況下可能導致絕收情形；後續以自製之 MCMV 及 SCMV 抗血清進行大規模調查，共計調查 4,551 個樣本，結果顯示 MCMV 全年罹病率逾 60% 以上，夏季罹病率遠低於冬春季種植期，冬春作發病高峰最高可達 100%，然而 MLN 罹病率則僅約 2.5% (未發表結果)。相較於各國的 MLN 罹病率，美國為 13%，肯亞 67.6%，衣索比亞 33.8–62.1%、盧安達 75%，厄瓜多爾 22.9%，剛果民主共和國 0%，台灣的 MLN 罹病率顯著低於除剛果民主共和國外之其他各國，因此在防治策略上應首重 MCMV 的媒介昆蟲防治，後續的抗病育種也應優先著重於抗 MCMV 的玉米品種育成。

誌謝

本文承蒙行政院農業委員會科技計畫 103 農科-6.2.3-農-C1、動植物防疫檢局 104-救助調整-檢-01、105-救助調整-檢-02 補助試驗經費，感謝曾梓璋先生、劉秋玉小姐在試驗上的協助，感謝鐘大焜先生、許宏文先生、林傳凱先生、廖宏洲先生、周義筆先生、虎尾科技大學生物科技系羅朝村教授、花蓮區農業改良場蔡依真小姐及台東區農業改良場林駿奇先生在田間採樣的協助，謹此誌謝。

引用文獻

Adams, I. P., V. A. Harju, T. Hodges, U. Hany, A. Skelton, S. Rai, M. K. Deka, J. Smith, A. Fox, B. Uzayisenga, A. Rutikanga, M. Rutherford, B. Ricthis, N. Phiri, and N. Boonham. 2014. First report of maize lethal necrosis disease in Rwanda. New Dis. Rep. 29:22.

Adams, I. P., D. W. Miano, Z. M. Kinyua, A. Wangai, E. Kimani, N. Phiri, R. Reeder, V. Harju, R. Glover, U. Hany, R. Souza-Richards, P. Deb Nath, T. Nixon, A. Fox, A. Barnes, J. Smith, A. Skelton, R. Thwaites, R. Mumford, and N. Boonham. 2013. Use of next-generation sequencing for the identification and characterization of *Maize chlorotic mottle virus* and *Sugarcane mosaic virus* causing maize lethal necrosis in Kenya. Plant Pathol. 62:741–749.

Cabanas, D., S. Watanabe, C. H. V. Higashi, and A. Bressan. 2013. Dissecting the mode of *Maize chlorotic mottle virus* transmission (Tombusviridae: Machlomovirus) by *Frankliniella williamsi* (Thysanoptera: Thripidae). J. Econ. Entomol. 106:16–24.

Castillo, J. and T. T. Hebert. 1974. A new virus disease of maize in Peru. Fitopatologia 9:79–84.

Chao, C. H., C. C. Chen, H. W. Chiang, and E. S. Wang. 1988. The occurrence of *Maize stripe virus* in Taiwan. Bull. Taichung Dist. Agric. Improv. Stat. 21:23–31.

Chen, C. C., T. Hsiang, F. L. Chiang, and C. A. Chang. 2002. Molecular characterization of *Tuberose mild mosaic virus* and preparation of its antiserum to the coat protein expressed in bacteria. Bot. Bull. Acad. Sin. 43:13–20.

Chiang, K. S., T. C. Deng, H. H. Lai, and S. F. Wang. 2007. A statistical method to estimate virus seed-transmission rate by results of group tests. Plant Pathol. Bull. 16:225–229. (in Chinese with English abstract)

Chou, C. M., F. C. Lin, T. C. Deng, Y. H. Chien, C. T. Chen, Y. J. Chen, C. H. Tsai, and H. W. Huang. 2015. The epidemic and transmission studies of *Maize chlorotic mottle virus*. p.31–42. *in*: Proceedings of the Symposium on Important New Emerging Crop Diseases in Taiwan and Their Controls. September 18, 2015. Taichung, Taiwan. Taiwan Agric. Res. Inst., Taichung, Taiwan. (in Chinese with English abstract)

Clark, M. F. and A. N. Adams. 1977. Characteristics of the microplate method of enzyme-linked immunosorbent assay for the detection of plant viruses. J. Gen. Virol. 34:475–483.

Colinet, D. and J. Kummert. 1993. Identification of a sweet potato feathery mottle virus isolate from China (SPFMV-CH) by the polymerase chain reaction with degenerate primers. J. Virol. Methods 45:149–159.

Delgadillo Sanchez, F. and R. Gaytan Beltran. 1987. Identificacion de la enfermedad de la “necrosis letal” del maiz en el estado de guanajuato. Rev. Mex.

Fitopatol. 5:21–26.

Deng, T. C. 1985. Identification of *Maize dwarf mosaic virus* B strain and screening for resistance of corn. J. Agric. Res. China 34:195–206. (in Chinese with English abstract)

Deng, T. C., C. M. Chou, C. T. Chen, C. H. Tsai, and F. C. Lin. 2014a. First report of *Maize chlorotic mottle virus* on sweet corn in Taiwan. Plant Dis. 98:1748.

Deng, T. C. and C. H. Huang. 1986. Purification and antiserum preparation of *Maize dwarf mosaic virus*. J. Agric. Res. China 35:350–359. (in Chinese with English abstract)

Deng, T. C., C. H. Tsai, C. M., Chou, and F. Y. Ning. 2014b. Molecular and serological characterizations of S*ugarcane mosaic virus* strains occurred in Taiwan. Plant Prot. Bull. 56:154–155. (in Chinese)

Fentahun, M., T. Feyissa, A. Abraham, and H. R. Kwak. 2017. Detection and characterization of *Maize chlorotic mottle virus* and *Sugarcanemosaic virus* associated with maize lethal necrosis disease in Ethiopia: an emerging threat to maize production in the region. Eur. J. Plant Pathol. 149:1011–1017.

Giegerich, R., F. Meyer, and C. Schleiermacher. 1996. GeneFisher-software support for the detection of postulated genes. Proc. Int. Conf. Intell. Syst. Mol. Biol. 4:68–77.

Goldberg, K. B. and M. K. Brakke. 1987. Concentration of *Maize chlorotic mottle virus* increased in mixed infections with *Maize dwarf mosaic virus*, strain B. Phytopathology 77:162–167.

Gong, H. Y., Y. J. Zhang, Z. Y. Zhang, H. J. Chen, B. D. Gao, and S. F. Zhu. 2010. Detection and identification of *Maize chlorotic mottle virus* from imported maize seeds. Acta Phytopathol. Sin. 40:426–429. (in Chinese with English abstract)

Jensen, S. G., D. S. Wysong, E. M. Ball, and P. M. Higley. 1991. Seed transmission of *Maize chlorotic mottle virus*. Plant Dis. 75:497–498.

Jiang, X. Q., L. J. Meinke, R. J. Wright, D. R. Wilkinson, and J. E. Campbell. 1992. *Maize chlorotic mottle virus* in Hawaiian-grown maize: Vector relations, host range and associated viruses. Crop Prot. 11:248–254.

Klinkong, T. and T. Sutabutra. 1982. A new virus disease of maize in Thailand. p.191–193. *in*: Proceedings of International Maize Virus Disease Colloquium and Workshop. August 2–6, 1982. Wooster, OH. The Ohio State Univ., Columbus, OH.

Kumar, S., G. Stecher, and K. Tamura. 2016. MEGA7: Molecular evolutionary genetics analysis version 7.0 for bigger datasets. Mol. Biol. Evol. 33:1870–1874.

Lei, Q. W., M. D. Li, M. Yuan, and Y. Y. Wang. 2013. Detection of *Maize chlorotic mottle virus* in maize seeds imported from Thailand. J. Huazong Agric. Unvi. 32:51–54. (in Chinese with English abstract)

Li, R. H., F. W. Zettler, D. E. Purcifull, and E. Hiebert. 1998. The nucleotide sequence of the 3'-terminal region of *Dasheen mosaic virus* (Caladium isolate) and expression of its coat protein in *Escherichia coli* for antiserum production. Arch. Virol. 143:2461–2469.

Liu, H. Y., Z. M. Liu, J. L. Zhang, and H. X. Zhang. 2011. Detection and identification of *Maize chlorotic mottle virus* from imported maize seeds. J. Northeast Agric. Univ. 42:36–40.

Lommel, S. A., A. H. McCain, and T. J. Morris. 1982. Evaluation of indirect enzyme-linked immunosorbent assay for the detection of plant viruses. Phytopathology 72:1018–1022.

Lukanda, M., A. Owati, P. Ogunsanya, K. Valimunzigha, K., Katsongo, H. Ndemere, and P. L. Kumar. 2014. First Report of *Maize chlorotic mottle virus* infecting maize in the Democratic Republic of the Congo. Plant Dis. 98:1448.

Mahuku, G., B. E. Lockhart, B. Wanjala, M. W. Jones, J. N. Kimunye, L. R. Stewart, B. J. Cassone, S. Sevgan, J. O. Nyasani, E. Kusia, P. L. Kumar, C. L. Niblett, A. Kiggundu, G. Asea, H. R. Pappu, A. Wangai, B. M. Prasanna, and M. G. Redinbaugh. 2015a. Maize lethal necrosis (MLN), an emerging threat to maize-based food security in sub-saharan Africa. Phytopathology 105:956–965.

Mahuku, G., A. Wangai, K. Sadessa, A. Teklewold, D. Wegary, D. Ayalneh, I. Adams, J. Smith, E. Bottomley, S. Bryce, L. Braidwood, B. Feyissa, B. Regassa, B. Wanjala, J. N. Kimunye, C. Mugambi, K. Monjero, and B. M. Prasanna. 2015b. First report of *Maize chlorotic mottle virus* and maize lethal necrosis on maize in Ethiopia. Plant Dis. 99:1870.

Nault, L. R., W. P. Styer, M. E. Coffey, D. T. Gordon, L. S. Negi, and C. L. Niblett. 1978. Transmission of *Maize chlorotic mottle virus* by chrysomelid beetles. Phytopathology 68:1071–1074.

Niblett, C. L. and L. E. Claflin. 1978. Corn lethal necrosis-a new virus disease of corn in Kansas. Plant Dis. Rep. 62:15–19.

Pappu, S. S., R. Brand, H. R. Pappu, E. P. Rybicki, K. H. Gough, M. J. Frenkel, and C. L. Niblett. 1993. A polymerase chain reaction method adapted for selective amplification and cloning of 3' sequences of potyviral genomes: application to *Dasheen mosaic virus*. J. Virol. Methods 41:9–20.

Pappu, S. S., H. R. Pappu, C. A. Chang, A. K. Culbreath, and J. W. Todd. 1998. Differentiation of biologi-

cally distinct peanut stripe potyvirus strains by a nucleotide polymorphism-based assay. Plant Dis. 82:1121–1125.

Quito-Avila, D. F., R. A. Alvarez, and A. A. Mendoza. 2016. Occurrence of maize lethal necrosis in Ecuador: A disease without boundaries? Eur. J. Plant Pathol. 146:705–710.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org (visit in 2013)

Scheets, K. 1998. *Maize chlorotic mottle machlomovirus* and *Wheat streak mosaic rymovirus* concentrations increase in the synergistic disease corn lethal necrosis. Virology 242:28–38.

Scheets, K. 2002. Machlomovirus. p.1179–1182. *in*: The Springer Index of Viruses. (Tidona, C. A., G. Darai, and C. Büchen-Osmond, eds.) Springer. Berlin, Germany. 1512 pp.

Sievers, F., A. Wilm, D. Dineen, T. J. Gibson, K. Karplus, W. Li, R. Lopez, H. McWilliam, M. Remmert, J. Söding, J. D. Thompson, and D. G. Higgins. 2011. Fast, scalable generation of high-quality protein multiple sequence alignments using Clustal Omega. Mol. Syst. Biol. 7:539.

Teyssandier, E. E., S. F. Nome, and E. Dal Bo. 1982. Maize virus diseases in Argentina. p.93–99. *in*: Proceedings of International Maize Virus Disease Colloquium and Workshop. August 2–6, 1982. Wooster, OH. The Ohio State Univ., Columbus, OH.

Uyemoto, J. K. 1983. Biology and control of *Maize chlorotic mottle virus*. Plant Dis. 67:7–10.

van der Vlugt, R. A. A. and M. Berendsen. 2002. Development of a general *Potexvirus* detection method. Eur. J. Plant Pathol. 108:367–371.

Valverde, R. A., J. A. Dodds, and J. A. Heick. 1986. Double-stranded ribonucleic acid from plants infected with viruses having elongated particles and undivided genomes. Phytopathology 76:459–465.

Wangai, A. W., M. G. Redinbaugh, Z. M. Kinyua, D. W. Miano, P. K. Leley, M. Kasina, G. Mahuku, K. Scheets, and D. Jeffers. 2012. First report of *Maize chlorotic mottle virus* and maize lethal necrosis in Kenya. Plant Dis. 96:1582.

Wu, J. X., Q. Wang, H. Liu, Y. Qian, Y. Xie, and X. P. Zhou. 2013. Monoclonal antibody-based serological methods for *Maize chlorotic mottle virus* detection in China. J. Zhejiang Univ. Sci. B 14:555–562. (in Chinese with English abstract)

Xie, L., J. Z. Zhang, Q. Wang, C. M. Meng, J. A. Hong, and X. P. Zhou. 2011. Characterization of *Maize chlorotic mottle virus* associated with maize lethal necrosis disease in China. J. Phytopathol. 159:191–193.

Zhao, M. F., H. H. Ho, Y. X. Wu, Y. Q. He, and M. J. Li. 2014. Western flower thrips (*Frankliniella occidentalis*) transmits *Maize chlorotic mottle virus*. J. Phytopathol. 162:532–536.

Phylogenetic Analysis and Occurrence of *Maize chlorotic mottle virus* Infecting Maize in Taiwan

Chien-Ming Chou[1], Chun-Tao Chen[2], Yi-Hsuan Chien[3], Chin-Hui Tsai[3], Chin-Chih Chen[1], Feng-Chyi Lin[4], Yi-Ju Chen[5], and Ting-Ching Deng[6,*]

Abstract

Chou, C. M., C. T. Chen, Y. H. Chien, C. H. Tsai, C. C. Chen, F. C. Lin, Y. J. Chen, and T. C. Deng. 2018. Phylogenetic analysis and occurrence of *Maize chlorotic mottle virus* infecting maize in Taiwan. J. Taiwan Agric. Res. 67(2):191–208.

Maize samples showing chlorotic, yellowing and leaf necrosis symptoms were collected in Huwei Township, Yunlin County in February 2014. After inoculation by leaf sap, the similar chlorotic mottle symptom was developed on sweet corn cv. 'Honey-236' and a pure virus isolate "NFU2" was obtained from infected sweet corn by a serial inoculation. The total RNA of "NFU2" isolate was extracted to conduct a reverse transcriptase polymerase chain reaction (RT-PCR) with the degenerate primer (Tenui-DF1/Tenui-DR1) and that yields a 1.4 kb product. The product could combine into one single contig, and this contig shared 99% sequence identities with Chinese *Maize chlorotic mottle virus* (MCMV) "Yunnan3" (Acc. No. JQ982469). The complete sequence of MCMV "NFU2" was as 4,436 nucleotides. Through whole genome sequence alignment and phylogenetic analysis revealed that MCMV could be divided into four groups, including American isolates, Chinese isolates, East African isolates and Taiwanese isolate. Phylogenetic analysis with nucleotide sequences of MCMV coat protein showed that MCMV isolates which were prevalent in Asia and Africa in recent years could possibly share the common ancestor of MCMV from Thailand. MCMV coat protein sequence was constructed into expression system of *Escherichia coli* Rosetta strain and the expressed viral coat protein was purified for antiserum production. Homemade MCMV antiserum could be used in enzyme-linked immunosorbent assay (ELISA) for MCMV detection in field samples. Furthermore, based on MCMV coat protein gene, a specific primer pair (MCMV-g3514F/MCMV-g4014R) for RT-PCR was developed, and by which the MCMV could be detected from a single maize thrip (*Frankliniella williamsi* Hood). These detection tools are available for further study of insect transmission mechanism of MCMV. Survey of 306 maize samples in Taiwan from 2014 to 2015 by indirect ELISA using antibodies against MCMV and/or *Sugarcane mosaic virus* (SCMV). The results indicated that incidence of MCMV reached 79.7% and maize lethal necrosis (MLN) caused by MCMV and SCMV reached 31.7%. Maize samples including sweet corns, white corns, waxy corns, forage corns and dent corns were all MCMV-infected. Sweet corn cv. 'Bright Jean' has the lower incidence (60%) among the green corn and comparing with incidence 31.6% of forage corn and dent corn. This is the first report about complete genome sequence, phylogenetic analysis, detection reagent development and field survey of MCMV infecting maize in Taiwan.

Key words: *Maize chlorotic mottle virus*, *Sugarcane mosaic virus*, Phylogenetic analysis, Detection reagent, Field survey.

Received: May 22, 2017; Accepted: October 23, 2017.

* Corresponding author, e-mail: tcde@tari.gov.tw

1 Assistant Research Fellows, Plant Pathology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

2 Associate Technical Specialist, Hsinchu Branch, Bureau of Animal and Plant Health Inspection and Quarantine, Taoyuan, Taiwan, ROC.

3 Research Assistants, Plant Pathology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

4 Associate Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

5 Assistant Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

6 Research Fellow, Plant Pathology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):209–217 (2018)
DOI: 10.6156/JTAR.201806_67(2).0006 研究報告

基因轉殖 PFLP 香蕉於促進抗香蕉黃葉病之研究

關政平[1] 陳柏亨[2] 陳涵葳[1,*] 馮騰永[3] 楊佐琦[4]

摘要

關政平、陳柏亨、陳涵葳、馮騰永、楊佐琦。2018。基因轉殖 PFLP 香蕉於促進抗香蕉黃葉病之研究。台灣農業研究 67(2):209–217。

由 *Fusarium oxysporum* f. sp. *cubense* (Foc) 引起之香蕉黃葉病已被認定為世界性的香蕉病害，目前仍無化學或殺菌劑可以有效防治。為減少黃葉病所造成香蕉產業損失，利用育種方式找出抗病品種或是藉發展抗病之基因轉殖香蕉為有效的防治手段之一。本研究旨在探討轉殖基因香蕉之抗病力，以及發展一種葉片分級評估系統來分析 Foc 對香蕉造成的危害，作為香蕉抗黃葉病之效果評估，試驗對象包括各個具有表現 plant ferredoxin-like protein (PFLP) 基因之各香蕉轉殖株。並利用 PFLP 基因之轉殖系與非 PFLP 基因轉殖之香蕉作為判斷是否具有抗香蕉黃葉病之效果。試驗過程同時加入等量之 Foc 孢子懸浮液與相同試驗條件感染香蕉，以評估各處理香蕉罹病情形，並藉由 polymerase chain reaction (PCR) 技術檢測外源基因之存在與否。轉殖系種植病土後經過不同時期至約 8 wk 左右，利用葉部黃葉率試驗評估法進行香蕉苗之抗黃葉病效果評估，並挑選出具抗病之香蕉植株。結果顯示，MCPER-3-4 轉殖株為 7 種供試轉殖株中相對最抗黃葉病的植株。由本研究結果顯示，PFLP 基因的存在似能提高香蕉抗黃葉病罹病率，未來將進行田間抗病的長期觀察做進一步驗證。

關鍵詞：香蕉、香蕉黃葉病、巴拿馬病、耐病性。

前言

香蕉 (*Musa* spp.) 為芭蕉科 (Musaceae) 芭蕉屬草本植物，原產於東南亞、馬來群島及澳洲北部，主要分布在熱帶及亞熱帶。根據農糧署統計資料顯示，2016 年台灣香蕉產量為 25 萬噸，年產值達 75 億元，是台灣重要的經濟果樹之一。但台灣地處熱帶及亞熱帶交界處，海島型氣候導致夏季高溫多雨，容易滋生各種病害且不易防治。出現在台灣的香蕉病害為真菌性的黃葉病 (*Fusarium* wilt)、黑星病 (banana freckle)，以及病毒性的嵌紋病 (banana mosaic disease) 和萎縮病 (banana bunchy top virus) 等 (Daniells 2009)。其中，香蕉黃葉病又稱巴馬拿病 (Panama disease)，其病原為尖鐮胞菌 (*Fusarium oxysporum* f. sp. *cubenses*; Foc)，為土傳性病害 (soil-borne disease)，生長型態包含了小孢子體 (microconidia)、大孢子體 (macroconidia)、厚膜孢子體 (chlamydospores) 以及菌絲體 (mycelia) (Smith 2007)。1968 年時在屏東縣佳冬鄉首次發現黃葉病例，香蕉黃葉病目前共發現有 4 個生理小種 (races)，各生理小種的宿主香蕉品種亦不盡相同。第一生理小種主要感染「大米七」(‘Gros Michel’)、「絲蕉」(‘Silk’) 和「馬尼拉麻」(‘Abaca’) 等品種；「棱指蕉」(‘Bluggoe’) 為第二生理小種之主要宿主；第三生理小種感染赫蕉系 (Heliconia)；而第四生理小種則以華蕉系 (Cavendish) 等亞洲主要栽培品種為宿主，亦造

投稿日期：2017 年 5 月 22 日；接受日期：2017 年 10 月 23 日。
* 通訊作者：swaychen@tari.gov.tw
1 農委會農業試驗所生物技術組助理研究員。台灣 台中市。
2 農委會農業試驗所生物技術組研究助理。台灣 台中市。
3 前中央研究院植物暨微生物學研究所研究員。台灣 台北市。
4 農委會農業試驗所生物技術組研究員兼組長。台灣 台中市。

成嚴重危害 (Sun & Huang 1996)。

近年來的研究顯示，由甜椒 (*Capsicum annuum* L.) 選殖出的植物類鐵氧化還原蛋白 (plant ferredoxin-like protein; PFLP)，在植物遭受病原菌感染時所產生的過敏反應 (hypersensitive response; HR) 中扮演重要角色 (Dayakar *et al*. 2003)。研究顯示，PFLP 具有促進植物受感染細胞中活性氧化物 (reactive oxygen species; ROS) 累積和過敏反應的功能 (Dayakar *et al*. 2003)。Tang *et al*. (2001) 的研究顯示，於水稻中表現分離自甜椒的 PFLP 基因，可強化水稻轉殖系對 *Xanthomonas* 的抗病能力；而 PFLP 過量表現之阿拉伯芥 (*Arabidopsis thaliana*) 轉殖系接種細菌性軟腐病後，亦顯示轉殖系能提升對軟腐病的抗性 (Su *et al*. 2014)。胞外分泌訊號胜肽 (extracellular secretion signal peptide; esp) 為一段位於蛋白質 N-terminal 的胺基酸序列，具有幫助於細胞內摺疊、修飾完畢之完整功能的蛋白質經由囊泡分泌至胞外之功能。Outchkourov *et al*. (2002) 將 equistatin 蛋白基因序列 N-terminal 加上一段 α-mating factor secretion signal 序列進行修飾，結果顯示該段修飾過的融合蛋白與未修飾之 equistatin 蛋白比較，能提高 20 倍以上的蛋白質累積量。內質網保留訊號 (endoplasmic reticulum retention signal) 為一段由 Lys-Asp-Glu-Leu 四個胺基酸分子所組成之胺基酸序列 (胺基酸序列縮寫為 KDEL)，C-terminal 帶有 KDEL 序列的蛋白質可在完成摺疊與修飾後再次運移至內質網 (Stornaiuolo *et al*. 2003)。Wandelt *et al*. (1992) 將碗豆球蛋白基因加上 KDEL 序列，並導入菸草及苜蓿等植物中表現，可見轉殖系中帶有 KDEL 序列之碗豆重組球蛋白累積量為未修飾的碗豆球蛋白的 20–100 倍，顯示 KDEL 序列對蛋白質之運移、穩定構形及儲存具有重要作用。

本研究嘗試建立香蕉黃葉病快速篩選流程，並以此篩選系統評估香蕉之抗病能力。研究內容包含：確認病原菌之病原性、接種方法與條件、黃葉病發病指標、發病時間等，藉此探討於香蕉中表現 PFLP 基因是否能增加轉殖系對於黃葉病之耐性或抗性，並比較未修飾的 PFLP 蛋白與帶有 esp 及 KDEL 序列之修飾 PFLP 蛋白對黃葉病抗性能力之差異。

材料方法

植物材料

本試驗所使用之基改香蕉材料為表現未修飾 PFLP 蛋白之 MVES-3、MVES-4、MVCS-6、MVCS-20 轉殖系，以及表現 esp 與 KDEL 修飾之 PFLP 蛋白的 MCPER-3-3、MCPER-3-4 轉殖系 (圖 1)，香蕉轉殖系植物材料均由中央研究院馮騰永研究員所提供。轉殖載體構築方式如 Dayakar *et al*. (2003) 所述，轉殖系能穩定表現 *pflp* 外源基因，並對黃葉病原 Foc race 4 具有抗性 (Yip *et al*. 2011)。本試驗另以 'Gros Michelc' 作為未轉殖 (WT) 之對照品系。本試驗所使用的香蕉苗均經組培繼代後，挑選大小一致之瓶

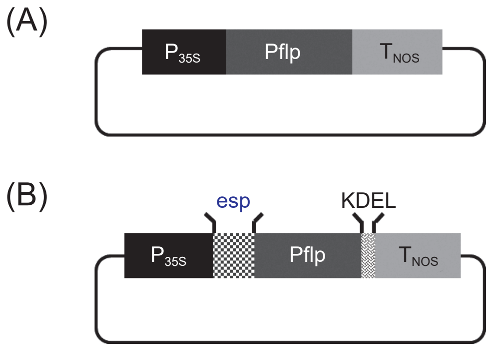


圖 1. (A) Plant ferredoxin-like protein (PFLP) 與 (B) MCPER 重組載體構築示意圖。esp 為胞外分泌訊號胜肽；KDEL 為內質網保留訊號。

Fig. 1. Construction of the recombinant plasmid (A) plant ferredoxin-like protein (PFLP) and (B) MCPER. esp, extra cellular secretion signal; and KDEL, endoplasmic reticulum retention signal.

苗，培養於 B3 固態培養基 (1/2 MS salts, 340 mg L^{-1} $NaH_2PO_4·H_2O$, 160 mg L^{-1} adenine sulfate, 3% sucrose, pH 5.5, 0.7% agar)，25℃ ± 2℃、12 h 光照環境，待培植體發根後出瓶，小苗定植後置於隔離溫室馴化。試驗前蕉苗均以聚合酶連鎖反應 (polymerase chain reaction; PCR) 檢測是否帶有外源基因，植物基因體 DNA 的萃取是使用 Plant Genomic DNA Purification Kit (PROTECH, Taiwan)，萃取方法依原廠手冊建議。確認帶有外源基因之香蕉轉殖系，於出瓶後 5 wk 後挑選整齊一致的植株進行後續接種試驗。

接種方法與條件

Foc 接種試驗參考 Twizeyimana *et al*. (2007) 及 Tripathi *et al*. (2008) 的接種方式，Foc 病原菌 (TBRI-3) 則取自財團法人台灣香蕉研究所 (Taiwan Banana Research Institute; TBRI)。Foc 之繼代培養使用 Difco™ Potato Dextrose Agar (Difco Laboratories, MI) 培養基，栽培介質培養方式為：Foc 菌塊於 Difco™ Potato Dextrose Broth (Difco Laboratories, MI) 液態搖盪培養 1 wk (28℃, 800× *g*) 後以 Cheese cloth 過濾去除菌絲，並搜集過濾後孢子液。利用離心法去除培養基。使用無菌水回溶孢子，並利用血球計數器計算孢子濃度，調整孢子液至試驗濃度 10^6 spores mL^{-1}。所有栽培介質皆經高溫高壓滅菌處理 (121℃, 20 min)，混合比例為根基旺：玉米粉：Foc 孢子濃度 10^6 spores mL^{-1} = 2,500：131：500 (mL) 後密封，於 28℃培養 1 mo。將培養 1 mo 之菌土：無菌根基旺 = 1：3 混合後使用。接種時，將香蕉幼苗移植至栽培介質中，培養於溫室 (溫度 25–28℃)，每個處理之香蕉品種為 5 株，並含有未處理之對照組，重複試驗至少 3 次。為避免 Foc 於土壤中的含量因環境因素或隨時間逐漸減少，於香蕉接種黃葉病菌 7 d 後，每週於栽培介質中加入一次 20 mL pot^{-1} 之 10^7 spores mL^{-1} 之 Foc 懸浮液，並在 1 wk 內澆灌適量的逆滲透 (reverse osmosis; RO) 水 3 次。

黃葉病之病徵判斷

本試驗所使用的香蕉黃葉病的病徵判斷方法，包括黃葉率、罹病指數以及假莖褐化率，判定方式分述如下：

$$\text{黃葉率} = \frac{\text{葉片黃化數}}{\text{全株葉片數}} \times 100\%$$

罹病嚴重程度 (disease severity index; DSI)，判定標準與分級如表 1 所列。

假莖褐化率 (corm discoloration %)

$$= \frac{\text{假莖切面褐化面積}}{\text{假莖切面總面積}} \times 100\%$$

香蕉假莖褐化率材料取樣自試驗 54 d 後之蕉苗假莖基部，拍攝假莖縱剖面照片，並利用 Image J 軟體 (http://imagej.nih.gov/ij/) 分析切面總面積與褐化面積。

結果與討論

接種用香蕉轉殖株分子驗證

以 PCR 檢測擬轉殖株 MVES-3、MVES-4、MVES-7、MVCS-6、MVCS-20 以及 MCPER-3-3、MCPER-3-4 基因組是否帶有外源基因，表 2 為檢測外源基因 P_{35S}::*pflp*::T_{nos} 及 P_{35S}::*MCPER*::T_{nos} 所使用的引子對。結果顯示，圖 2A 中 MVES-3、MVES-4、MVES-7 以及 MVCS-6、MCVS-20 轉殖系，皆有 545 bp 之目標基因條帶檢出。圖 2B 為 MCPER-3-3 與 MCPER-3-4，亦檢測出 844 bp 之目標片段，“W” 為不帶有模板 DNA 之空白試驗對照組；“–” 為未轉殖 ‘Gros Michel’ 香蕉負對照組；“+” 則為帶有 PFLP 基因之質體 DNA 正處理組。結果顯示轉殖株 MVES-3、MVES-4、MVES-7、MVCS-6、MVCS-20、MCPER-3-3、MCPER-3-4 之 PCR 結果與正處理

表 1. 黃葉病之罹病指標說明。

Table 1. Disease severity index (DSI) of *Fusarium* wilt disease.

Score	Appearance
0	No visible symptoms
1	0–1/4 leaves wilted or yellowed
2	1/4–1/3 leaves wilted or yellowed
3	1/3–1/2 leaves wilted or yellowed
4	1/2–3/4 leaves wilted or yellowed
5	All leaves wilted/plant dead

表 **2.**　聚合酶連鎖反應使用的引子對序列與產物片段大小。

Table 2.　Primer sequence and target size of polymerase chain reaction.

Construct	Event	Primer seq.	Target size (bp)
P_{35S}::*pflp*::T_{nos}	MVES-3, MVES-4, MVES-7, MVCS-6, MVCS-20	5’-aagggatgacgcacaatcccactatccttc-3’ 5’-cgagctcgttagcccacgagttctgcttct3’	545
P_{35S}::*MCPER*::T_{nos}	MCPER-3-3, MCPER-3-4	5’-aagggatgacgcacaatcccactatccttc-3’ 5’-cccagtcacgacgttgtaaa-3’	844

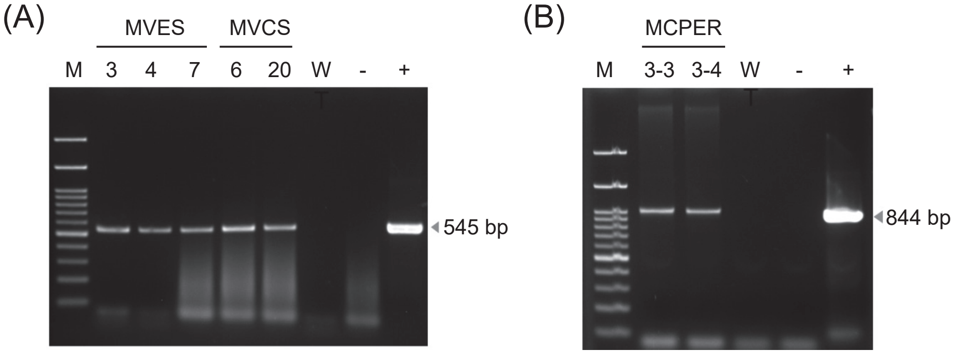


圖 2. 箭號標示處為目標片段大小。Lane M 為 marker，Lane W 為沒有加入 DNA 的空白對照組，Lane – 為負控制組的未轉殖 ‘Gros Michel’ 基因組 DNA，Lane + 則為帶有 *pflp* 基因片段的正控制組，轉殖系 MVES-3、MVES-4、MVES-7、MVCS-6、MVCS-20、MCPER-3-3、MCPER-3-4 依序標示於圖上。

Fig. 2. Foreign gene detection of transgenic banana lines *pflp* (A) and MCPER (B). Arrows showed the target size. Lane M, DNA ladder marker; Lane W, the blank control without any DNA templates in the PCR reactions; Lane “–”: non-transgenic ‘Gros Michel’ gDNA as negative control; and Lane “+”: plasmid DNA with *pflp* gene fragment as positive control. Lane 3: MVES-3; Lane 4: MVES-4; Lane 7: MVES-7; Lane 6: MVCS-6; Lane 20: MVCS-20; Lane 3-3: MCPER-3-3; and Lane 3-4: MCPER-3-4.

組具有相同片段大小條帶，確定參試之香蕉苗均帶有目標基因。

香蕉轉殖株對黃葉病之抗性檢測

參試香蕉品系移植入帶有黃葉病病原菌之土壤中進行接種，以評估各品系香蕉對於黃葉病之抗性。圖 3 為接種後 54 d 後之植株於溫室生長情形，轉殖系 MCPER-3-4 植株不具明顯病徵，且生長狀態良好，其餘香蕉植株除生長較緩慢、植株生長勢較弱外，亦出現葉片黃化、萎凋等情形。圖 4A 為調查香蕉各處理組的葉片黃化率。結果顯示，MCPER-3-4 香蕉植株之葉片黃化率 10%，遠低於其他轉殖系，且已達 5% 顯著水準，具有顯著差異。感病率第二低的則為 MCPER-3-3 轉殖株 (黃化率 30%)，但與其他轉殖系均未達顯著水準。另以罹病嚴重程度 (Disease severity index; DSI) 統計感病率，圖 4B 顯示 MCPER-3-3 於接種後 32 d DSI 開始輕微上升，接種後 46 d DSI 開始明顯上升；MCPER-3-4 於接種後 37 d 後檢測到 DSI 的上升，於 46 d 至 54 d 期間則無明顯 DSI 變化，其餘轉殖株則於接種後 32 d 開始出現大量病徵，致 DSI 急遽上升，DSI 檢測結果與葉片黃化比率相符。比較兩者並經檢測感病情形，最輕微者皆為轉殖系 MCPER-3-4。檢測香蕉假莖之褐化率，比較接種處理組之假莖縱切面 (圖 5)，顯示 MCPER-3-4 具有較低之假莖褐化率 (30.22%)，其餘依次為 MVCS-6 (33.68%)、MVES-4 (35.42%)、MCPER-3-3 (39.66%)、MVES-7 (40.43%)、V215 (41.44%)、MVES-3 (53.77%)，假莖褐化率最高者為 MVCS-20 (64.52%) (表 3)。

PFLP 蛋白參與光合作用，其 N-terminal 具有可使 PFLP 蛋白質運移至葉綠體之訊號胜肽。

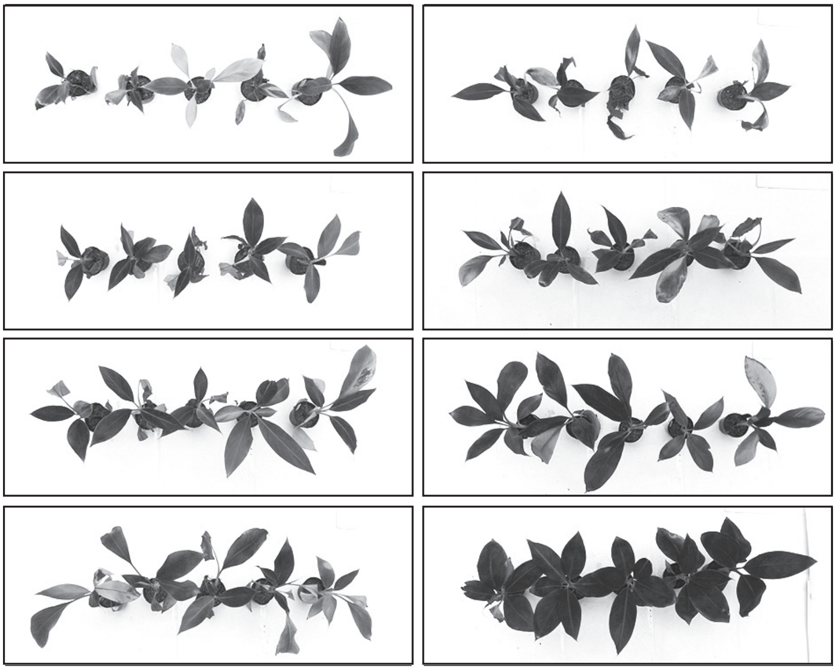


圖3. 参試品種對*Fusarium oxysporum* f. sp. *cubense* (Foc) 耐受性評估。以 ‘Gros Michel’ 作為未轉殖對照品系，與轉殖系 MVES-3、MVES-4、MVES-7、MVCS-6、MVCS-20、MCPER-3-3、MCPER-3-4 皆於接種後 54 d 進行照片拍攝。

Fig. 3. *Fusarium oxysporum* f. sp. *cubense* (Foc) disease tolerance of different banana lines. Non-transgenic ‘Gros Michel’ and transgenic lines MVES-3, MVES-4, MVES-7, MVCS-6, MVCS-20, MCPER-3-3, and MCPER-3-4 were inoculated in greenhouse condition. Photos were taken at 54 d post inoculation.

表 3. 香蕉轉殖系與未轉殖品系接種 *Fusarium oxysporum* f. sp. *cubense* (Foc) 後假莖褐化率。

Table 3. Discoloration level of *Fusarium oxysporum* f. sp. *cubense* (Foc) inoculated non-transgenic and transgenic banana lines.

Line	Discoloration (%)[z]
‘Gros Michel’ (WT)	41.44 ± 25.84 abc
MVES-3	53.77 ± 14.00 ab
MVES-4	35.42 ± 17.36 bc
MVES-7	40.43 ± 23.18 bc
MVCS-6	33.68 ± 8.36 bc
MVCS-20	64.52 ± 25.00 a
MCPER-3-3	39.66 ± 8.61 bc
MCPER-3-4	30.22 ± 11.99 c

[z] Discolored region and total area of corm were determined by Image J. Percentage of discolored area = (discolored region/ total corm area) × 100%. Mean ± standard error (n = 5). Means followed by the same letter within each column are not significantly differentat 5% level by least significant difference (LSD) test.

前人研究結果顯示，去除 PFLP N-terminal 之葉綠體訊號胜肽，能夠於細胞質中檢測到大量 PFLP 之累積，並且同樣地具有抗菌效果 (Huang *et al*. 2006)。Lin *et al*. (2010) 分別構築去除 PFLP N-terminal 葉綠體訊號胜肽之 PFLP 過量表現質體 (*d-pflp*)；帶有葉綠體訊號胜肽之 PFLP 過量表現質體 (*csp-pflp*)；以及 N-terminal 帶有胞外分泌訊號胜肽之 PFLP 過量表現質體 (*esp-pflp*)，再將上述三質體透過農桿菌 (*Agrobacterium tumefaciens*) 基因轉殖分別導入阿拉伯芥基因組中。結果顯示，*esp-pflp* 阿拉伯芥轉殖株於接種 *Ralstonia solanacearum* 病原菌後，其罹病指標低於未轉殖株及其他轉殖株，且過敏反應檢測結果亦顯示 *esp-pflp* 轉殖株具有較高之過敏反應。經由葉片黃化率和罹病嚴重指數之統計結果顯示，MCPER-3-4 轉殖株對黃葉病有明顯的抗性，具有成為抗黃葉病之香蕉品種的潛力，其次為由同一轉殖母株分離之 MCPER-3-3 轉殖

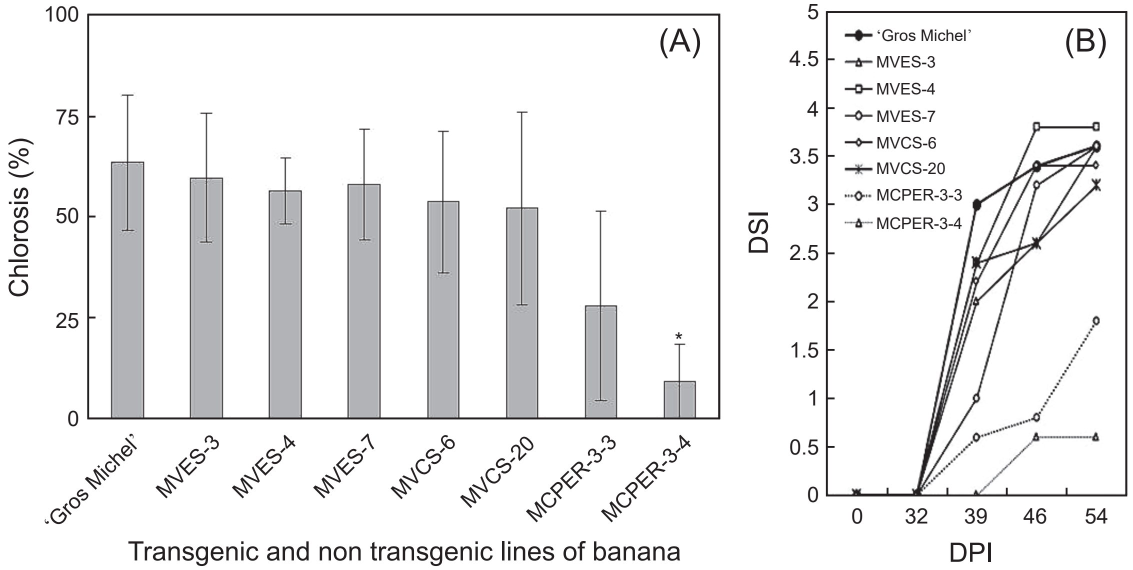


圖 4. 各轉殖系及未轉殖香蕉黃葉率與罹病嚴重程度。(A) 各品系香蕉植株黃葉率 (54 dpi)。資料經由 ANOVA 和 Tukey's test 計算後具顯著性差異則標示 * (α = 0.05)，試驗進行 5 重複；(B) 各品系香蕉罹病嚴重程度 (Disease severity index; DSI)，調查於接種後第 0、32、39、46 與 54 d。

Fig. 4. Percentage of chlorosis leaves and disease severity index of different transgenic and non transgenic line of bananas. (A) Percentage of yellowing leaves per seedlings were estimated at 54 dpi. Data were analyzed by one-way ANOVA and Tukey's test. Group with star represents a statistically significant difference among them (α = 0.05); (B) Disease severity index (DSI) of different transgenic and non-transgenic line of bananas were estimated at 0, 32, 39, 46, and 54 d.

株。另 MVES-4 和 MVCS-6 轉殖株接種後 54 d 之葉片黃化率分別為 MVES-4 57%、MVCS-6 55%，略低於未轉殖株但無顯著差異。由此顯示，於 PFLP 基因的 N-terminal 及 C-terminal 分別接上 esp 和 KDEL 序列之 CPER 轉殖系，確實提高了轉殖株的抗病性，且與未轉殖株具顯著差異；然而 CPER 轉殖系之高抗病能力是否與 PFLP 蛋白質的穩定度和表現量有關，仍須進一步的比較 PFLP 轉殖系與 CREP 轉殖系中 PFLP 基因表現量及蛋白質含量與轉殖株感病性之相關性。假莖褐化率檢測結果與葉片黃化率及罹病嚴重指數不符，假莖褐化率最低之轉殖株為 MCPER-3-4 (30.22%)，其次為 MVCS-6 轉殖株 (33.68%)。然而，葉片黃化率最低者，同樣為 MCPER-3-4，其次卻為 MCPER-3-3 轉殖株，顯示假莖褐化率與葉片黃化率兩檢測方法之結果不具直接相關性。推測可能原因，為檢測樣本數量不足。另也必須延長接種時間，讓受黃葉病感染之香蕉植株，其假莖褐化情形能夠有足夠時間反應至地上部的葉片上，使得葉片黃化與假莖褐化出現較為一致的結果。

結論

利用接種黃葉病病原篩選轉殖系香蕉試驗，同時比較基因轉殖香蕉與非轉殖香蕉，綜合使用黃葉率、罹病率分析及假莖褐化率等做評估，顯示具表現 PFLP 香蕉，與帶有 *esp-pflp* 融合蛋白之轉殖系，具有較佳之抗黃葉病能力，未來仍將以田間抗病的長期觀察做進一步驗證。

誌謝

本研究承蒙行政院農業委員會科技計畫 (103–104 農科-6.3.2-農-C1) 經費支援，以及中研院馮騰永研究員提供香蕉轉殖系作為試驗材料，謹此致謝。

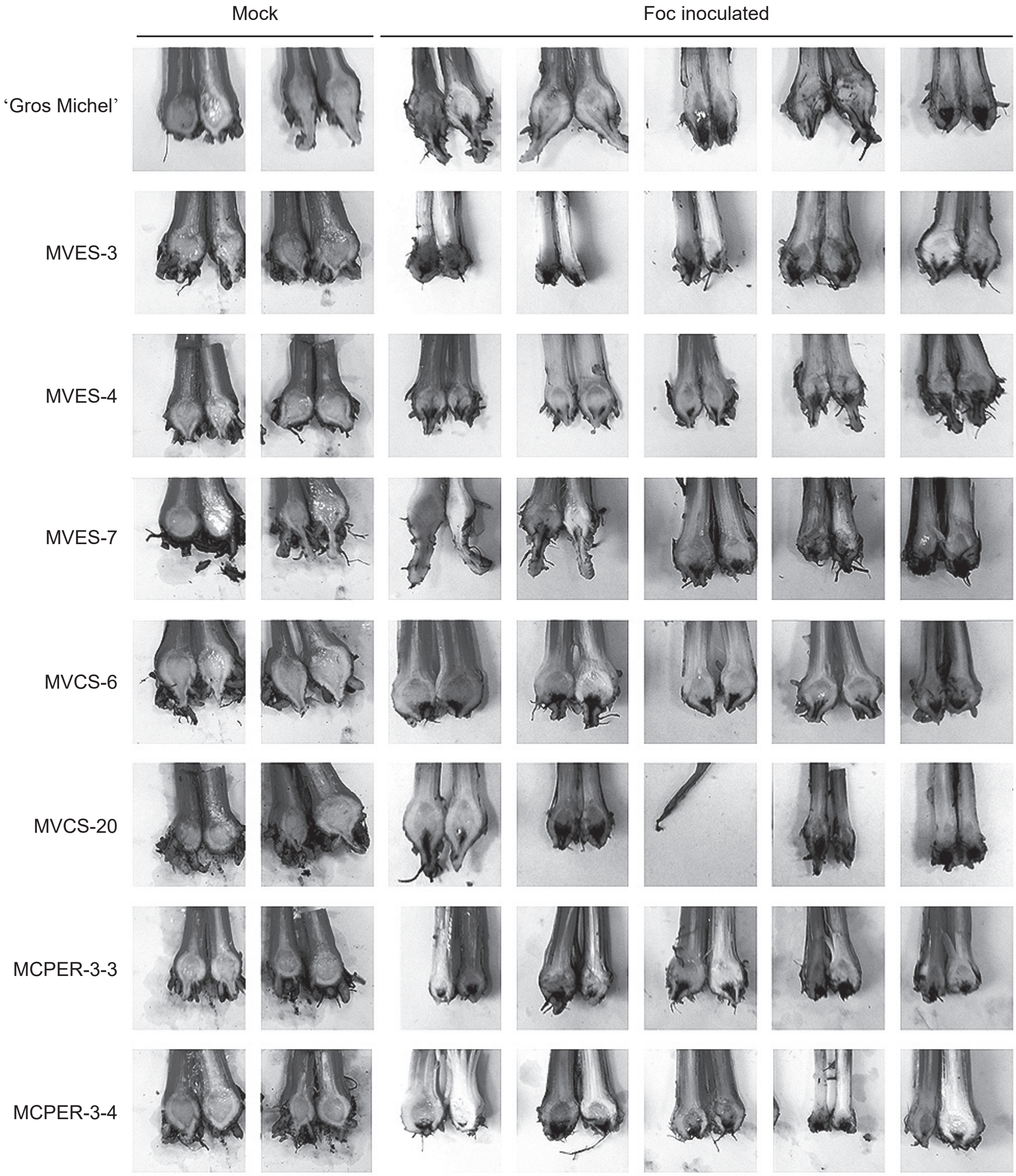


圖 5. 不同香蕉品系假莖縱切檢測。以 'Gros Michel' 作為未轉殖對照品系，與轉殖系 MVES-3、MVES-4、MVES-7、MVCS-6、MVCS-20、MCPER-3-3、MCPER-3-4，分別接種沒有 *Fusarium oxysporum* f. sp. *cubense* (Foc) 孢子的純水 (mock)，與孢子懸浮液，並於接種後 54 d 進行照片拍攝。

Fig. 5. The symptoms of *Fusarium oxysporum* f. sp. *cubense* (Foc) inoculation in different banana lines. Non-transgenic 'Gros Michel' and transgenic lines MVES-3, MVES-4, MVES-7, MVCS-6, MVCS-20, MCPER-3-3, and MCPER-3-4 were inoculated with Foc free water (mock) or Foc spore suspension in greenhouse condition. Images of cross-section were recorded at 54 d post inoculation.

引用文獻

Daniells, J. W. 2009. Global banana disease management-Getting serious with sustainability and food security. Acta Hort. 828:411–416.

Dayakar, B. V., H. J. Lin, C. H. Chen, M. J. Ger, B. H. Lee, C. H. Pai, D. Chow, H. E. Huang, S. Y. Hwang, M. C. Chung, and T. Y. Feng. 2003. Ferredoxin from sweet pepper (*Capsicum annuum* L.) intensifying harpin (PSS)-mediated hypersensitive response shows an enhanced production of active oxygen species (AOS). Plant Mol. Biol. 51:913–924.

Huang, H. E., M. J. Ger, C. Y. Chen, M. K. Yip, M. C. Chung, and T. Y. Feng. 2006. Plant ferredoxin-like protein (PFLP) exhibits an anti-microbial ability against soft-rot pathogen *Erwinia carotovora* subsp. *carotovora in vitro* and *in vivo*. Plant Sci. 171:17–23.

Lin, Y. H., H. E. Huang, F. S. Wu, M. J. Ger, P. L. Liao, Y. R. Chen, K. C. Tzeng, and T. Y. Feng. 2010. Plant ferredoxin-like protein (PFLP) outside chloroplasts in *Arabidopsis* enhances disease resistance against bacterial pathogens. Plant Sci. 179:450–458.

Outchkourov, N. S., W. J. Stiekema, and M. A. Jongsma. 2002. Optimization of the expression of equistatin in *Pichia pastoris*. Protein Exp. Purif. 24:18–24.

Smith, S. N. 2007. An overview of ecological and habitat aspects in the genus *Fusarium* with special emphasis on the soil borne pathogenic forms. Plant Pathol. Bull. 16:97–120.

Stornaiuolo, M., L. V. Lotti, N. Borgese, M. R. Torrisi, G. Mottola, G. Martire, and S. Bonatti. 2003. KDEL and KKXX retrieval signals appended to the same reporter protein determine different trafficking between endoplasmic reticulum intermediate compartment and Golgi complex. Mol. Biol. Cell 14:889–902.

Sun, S. G. and J. W. Huang. 1996. Plant Disease Caused by Fusarium in Taiwan. Shih Wei Press. Taichung, Taiwan. 170 pp. (in Chinese)

Su, Y. H., C. Y. Hong, and Y. H. Lin. 2014. Plant ferredoxin-like protein enhances resistance to bacterial soft rot disease through PAMP-triggered immunity in *Arabidopsis thaliana*. Eur. J. Plant Pathol. 140:377–384.

Tang, K., X. Sun, Q. Hu, A. Wu, C. H. Lin, H. J. Lin, R. M. Twyman, P. Christou, and T. Feng. 2001. Transgenic rice plants expressing the ferredoxin-like protein (AP1) from sweet pepper show enhanced resistance to *Xanthomonas oryzae* pv. *oryzae*. Plant Sci. 160:1035–1042.

Tripathi, L., J. Odipio, J. N. Tripathi, and G. Tusiime. 2008. A rapid technique for screening banana cultivars for resistance to *Xanthomonas* wilt. Eur. J. Plant Pathol. 121:9–19.

Twizeyimana, M., P. S. Ojiambo, A. Tenkouano, T. Ikotun, and R. Bandyopadhyay. 2007. Rapid screening of *Musa* species for resistance to black leaf streak using *in vitro* plantlets in tubes and detached leaves. Plant Dis. 91:308–314.

Wandelt, C. I., M. R. I. Khan, S. Craig, H. E. Schroeder, D. Spencer, and T. J. V. Higgins. 1992. Vicilin with carboxy-terminal KDEL is retained in the endoplasmic reticulum and accumulates to high levels in the leaves of transgenic plants. Plant J. 2:181–192.

Yip, M. K., S. W. Lee, K. C. Su, Y. H. Lin, T. Y. Chen, and T. Y. Feng. 2011. An easy and efficient protocol in the production of pflp transgenic banana against *Fusarium* wilt. Plant Biotechnol. Rep. 5:245–254.

Improving Resistance to *Fusarium* Wilt Disease in PFLP Transgenic Bananas

Cheng-Ping Kuan[1], Po-Heng Chen[2], Han-Wei Chen[1,*], Teng-Yung Feng[3], and Tso-Chi Yang[4]

Abstract

Kuan, C. P., P. H. Chen, H. W. Chen, T. Y. Feng, and T. C. Yang. 2018. Improving resistance to *Fusarium* wilt disease in PFLP transgenic bananas. J. Taiwan Agric. Res. 67(2):209–217.

Fusarium wilt disease of banana (Panama disease), caused by *Fusarium oxysporium* f. sp. *cubense* (Foc), is considered as one of the most important banana diseases in the world and no chemical control or fungicides are available so far. To decrease the damages of *Fusarium* wilt on banana industry, planting resistant cultivars and breeding the transgenic bananas expressing resistant genes against pathogens are best strategy in the Foc-infected field. Here, we developed a foliar rating system to assess the disease-development of *Fusarium* wilt in several transgenic banana plants expressing the ferredoxin-like protein (PFLP) gene. The responses of the PFLP transgenic and non-transgenic banana cultivars were evaluated on their susceptibility or tolerance against the pathogen in pots in the greenhouse. The PFLP gene in transgenic bananas were monitored by PCR to confirm its existence. Several transgenic lines of plantlets were challenged by the infection with the conidia suspension of Foc. Leaves yellowing or wilting symptoms of banana seedlings appeared over 8 weeks after Foc-inoculation. The results showed that the 'MCPER3-4' was the more resistant line among seven transgenic lines. This fast and space-effective bioassay may be used to evaluate as screening of *Musa* spp. against the disease.

Key words: Banana, *Fusarium* wilt, Panama disease, Tolerance.

Received: May 22, 2017; Accepted: October 23, 2017.
* Corresponding author, e-mail: swaychen@tari.gov.tw
1 Assistant Research Fellows, Biotechnology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.
2 Research Assistant, Biotechnology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.
3 Former Research Fellow, Institute of Plant and Microbial Biology, Academia Sinica, Taipei, Taiwan, ROC.
4 Research Fellow and Director, Biotechnology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):218–223 (2018)
DOI: 10.6156/JTAR.201806_67(2).0007

長莖全爪蟎 (*Panonychus elongatus* Manson) (絨蟎目：葉蟎科) —一種新興的害蟎

何琦琛 [1,*]　王順成 [2]　梁世祥 [3]　張淑貞 [4]

摘要

何琦琛、王順成、梁世祥、張淑貞。2018。長莖全爪蟎 (*Panonychus elongatus* Manson) (絨蟎目：葉蟎科) —一種新興的害蟎。台灣農業研究 67(2):218–223。

2007–2010 年間在高山水蜜桃園發現長莖全爪蟎 (*Panonychus elongatus* Manson) 為害，在平地水蜜桃園主要發現神澤氏葉蟎 (*Tetranychus kanzawai* Kishida) 為害，並記錄了長莖全爪蟎族群中所發現的捕食性天敵。

關鍵詞：水蜜桃、葉蟎、捕食性天敵。

前言

台灣為害農作物的葉蟎種類歷來均以葉蟎屬 *Tetranychus* 為主，小爪蟎屬 *Oligonychus* 與全爪蟎屬 *Panonychus* 為次，葉蟎屬主要發生的有神澤氏葉蟎 (*Tetranychus kanzawai* Kishida)、二點葉蟎 (*Tetranychus urticae* Koch)、赤葉蟎 (*Tetranychus cinnabarinus* Boisduval)、截形葉蟎 (*Tetranychus truncatus* Ehara)，小爪蟎屬主要是為害茶樹的茶葉蟎 [*Oligonychus coffeae* (Neitner)] 與為害芒果樹的芒果葉蟎 [*Oligonychus mangiferus* (Rahman and Sapra)]，全爪蟎屬則以柑桔葉蟎 [*Panonychus citri* (McGregor)] 為主 (Ho *et al*. 1995, 1997)，間以歐洲葉蟎 [*Panonychus ulmi* (Koch)] 在梨山地區為害蘋果及梨 (Wu & Lo 1979; Lo *et al*. 1986; Ho *et al*. 2011)。其後荔枝葉蟎 (*Oligonychus litchii* Lo & Ho) 在廿世紀末、廿一世紀初，發展成為台灣數種農作物上的主要害蟎，躍身而為台灣為害農作物的重要害蟎之一 (Ho 2004; Ho *et al*. 2013)。

高山水蜜桃為台灣近十餘年來極受歡迎之水果，水分多、香、甜，售價俏，深受消費者及農友喜愛。在桃園縣復興鄉巴陵地區、新竹縣尖石鄉、台中市和平區梨山村、平等村、南投縣仁愛鄉翠峰、高雄市那瑪夏區、花蓮縣秀林鄉洛韶均有高山水蜜桃栽植區。筆者於 2007–2010 年間調查溫帶果樹害蟎時，發現長莖全爪蟎 (*Panonychus elongatus* Manson) 已發展成高山水蜜桃果園中主要發生之害蟎，將台灣為害農作物之重要經濟害蟎又添一種。特將調查期間所獲有關長莖全爪蟎之資料披露於此，供農友及植物保護同仁參考。

材料與方法

前往台灣各高山水蜜桃栽培區，在高山水蜜桃園中尋找葉蟎，發現葉蟎族群或為害狀後，摘取被害葉片，置於封口袋中，攜回實驗室，於解剖顯微鏡下檢視，挑選雌雄成蟎，以 Hoyer's medium 製作玻片標本；雄蟎需製作陽莖 (aedeagus) 之側面標本。於 45℃烘箱中烘烤 1 wk，而後在光學顯微鏡下鑑定種類。同時記錄其上所發現之捕食性天敵。

投稿日期：2017 年 4 月 7 日；接受日期：2017 年 10 月 24 日。
[*] 通訊作者：mtho2005@yahoo.com.tw
[1] 農委會農業試驗所應用動物組前研究員。台灣 台中市。
[2] 朝陽科技大學環境工程與管理學系教授。台灣 台中市。
[3] 農委會畜產試驗所新竹分所助理研究員。台灣 苗栗縣。
[4] 農委會農業試驗所應用動物組助理研究員。台灣 台中市。

此期間亦在其他地區調查葉蟎，間或採得長莖全爪蟎，並記錄有關天敵資料。

結果

2007–2010 年間，筆者等在前述之高山水蜜桃產區調查，採得長莖全爪蟎之記錄如表 1，族群中觀察到之捕食性天敵亦列於表中。高山水蜜桃園多位於海拔 700 m 以上之山區，在此高度以上，平地水蜜桃園極為少見，幾全為高山水蜜桃園。採收以前，農友所採防治方法極為有效，無論高山水蜜桃或平地水蜜桃，葉片清潔翠綠，不見葉蟎蹤跡；僅未防治園方有可能發現葉蟎。在花蓮縣秀林鄉洛韶所調查之高山水蜜桃園，即為未防治園，長莖全爪蟎密度極高，佈滿葉片之上下兩面。高山水蜜桃採收後，相當時間內，農民不在桃園施藥，幾乎每個桃園中均可見到葉蟎族群，亦皆為長莖全爪蟎。

此期間亦曾調查數平地水蜜桃園 (俗稱甜桃者，為七分熟之平地水蜜桃)，部分亦發現此蟎為害，有關資料及捕食性天敵發生情形列於表 2。平地水蜜桃園一般發生葉蟎屬之葉蟎，筆者之資料中，採得雄蟎而鑑定得種類者，為復興鄉上巴陵、新竹縣尖石鄉泰崗及玉峰平地水蜜桃中採得之神澤氏葉蟎；在台中市和平區梨山村 (主要在省道 7 甲沿線)，可能受梨園之二點葉蟎族群影響，二點葉蟎盛行於該地之小面積桃園或零星桃樹上。此外，和平區往東勢方向之桃樹，曾發現柑桔葉蟎之族群。平地水蜜桃亦能發生長莖全爪蟎為害，能發生至高數量，密布全葉，或全株受害，但筆者未見全園發生長莖全爪蟎之平地水蜜桃園。

不論高山水蜜桃或平地水蜜桃，長莖全爪蟎主要棲息於葉背，也會前往葉面。一般棲息於葉背之葉蟎，在葉背之密度甚高後，才會移往葉面棲息。長莖全爪蟎不然，往往葉背上族群密度不很高時，即有雌成蟎前往葉面產卵，建立棲群。數量少時，大體沿中肋分布，但在葉尖處可能散開；而後順主要支脈擴散，而及於葉脈間之區域。

表 1. 長莖全爪蟎在高山水蜜桃上的採集紀錄及相關天敵。

Table 1. Collection records of *Panonychus elongatus* on high land peach and associated predators.

Location	Date	m.a.s.l[z]	Coordinate	Predators associated[y]
Xiulin, Hualien County				
Loshao	2007/7/30	1,146 m	N25°1’ 11.1”, E121° 27’ 12.3”	phytoseiids, larvae of ceccidomyiid
Upper Baling, Fushing, Taoyuan County				
Shanbaling	2008/9/10	1,232 m	N24°41’55.5”, E121°24’31.2”	
Beverly Villa	2007/7/18、2008/9/10	1,147 m	N24°41’18.0”, E121°23’40.7”	
Police station	2008/7/7	1,176 m	N24°41’08.5”, E121°23’55”	
Jianshih, Hsinchu County				
Yufeng	2008/9/10	776 m	N24°40’23.4”, E121°19’58.6”	
Yufeng	2008/9/10	789 m	N24°39’38.9”, E121°17’25.7”	
Taigang	2008/7/23	1,125 m	N24°36’31.2”, E121°17’1.3”	*Oligota* beetle
Taigang	2008/7/24	1,027 m	N24°36’39.9”, E121°17’5.1”	Larvae of *Oligota* and ceccidomyiid
Taigang	2008/9/9	1,005 m	N24°36’46.5”, E121°16’35.3”	
Taigang	2008/9/9	1,120 m	N24°36’37.7”, E121°16’31.2”	*Amblyseius*
Namaxia, Kaohsiung City				
Maya	2009/7/21	759 m	N23°14’32.3”, E120°42’7.1”	*Amblyseius maai*, *Oligota* (larvae)

[z] m.a.s.l: Meters above sea level.

[y] Predator that was observed to feeding on *P. elongatus* is underlined.

表 **2.** 長莖全爪蟎在平地水蜜桃上的採集紀錄及相關天敵。

Table 2. Collection records of *Panonychus elongatus* on low land peach and associated predators.

Location	Date	m.a.s.l[z]	Coordinate	Predators associated[y]
Baling, Fushing, Taoyuan County				
Beverly Villa	2007/7/18	1154 m	N24°41’11.4”, E121°24’11.3”	*Amblyseius herbicolus*
	2008/7/8	1154 m	N24°41’12.0”, E121°24’13.1”	Stigmaeidae, dark red in color, may had fed on *P. elongatus*.
Jianshih, Hsinchu County				
Hsinler	2008/7/23	346 m	N23°43’31.7”, E121°13’12.5”	
Hsinler	2008/7/23	438 m	N24°43’45.9”, E121°14’43.3”	
Taichung City				
Datei, Hoping	2008/10/21	639 m	N24°11’14.5”, E120°53’0.2”	*Amblyseius maai, A. ovalis*, cecidomyiid larva, *Oligota* sp.
Ruanbeikong, Qingfu, Tungshih	2009/9/23	494 m	N24°11’31.9”, E120°51’17.3”	Various stages of *A. herbicolus*

[z] m.a.s.l: Meters above sea level.
[y] Predator that was observed to feeding on *P. elongatus* is underlined.

數年來亦曾在其他植物上採得長莖全爪蟎，有關資訊列於表 3。在這些植物上，長莖全爪蟎亦主要棲息於葉背，但亦會分布至葉面。在葉上之分布仍以中肋兩側優先，而後主要支脈，再及於支脈間之區域。然此原則並非絕對，常有未沿中肋至底即順支脈而去；或是沿中肋分布之後，即分布於支脈間之區域者。

在長莖全爪蟎族群中或附近發現之捕食性天敵，包括捕植蟎 (Phytoceiidae)、捕食性癭蚋 (Cecidomyiidae)、小黑隱翅蟲 (*Oligota* sp.)、長鬚 (網背) 蟎 (Stigmaeidae)、巨鬚蟎 (Cunaxidae)。其中，曾觀察到捕食性癭蚋之幼蟲及小黑隱翅蟲捕食長莖全爪蟎；另外，有些樣品中之長鬚蟎體色暗紅 (一般見到時，較為鮮紅)，植綏蟎 *Phytoseius* sp. 體有紅痕 (一般無紅痕)，通常採得者均非如此，而葉片上無其他可供為食物之紅色生物，懷疑其曾取食長莖全爪蟎。

討論

Tseng (1990) 於台灣葉蟎專論中記錄 6 種全爪蟎，包括長莖全爪蟎，但他所繪之長莖全爪蟎陽莖長而直，與國外文獻不同。長莖全爪蟎為 Manson (1963) 以單隻雄蟎所發表的種類，而後又採得各齡期予以描述 (Manson 1968)。在此兩篇文章中所描繪之陽莖圖均為長而彎曲者，且 Manson (1968) 指出長莖全爪蟎與柑桔葉蟎近似，特別與柑桔葉蟎各齡期做形態比較，柑桔葉蟎之陽莖為 S 型。此均指出長莖全爪蟎之陽莖是呈 S 狀彎曲的。如是，Tseng (1990) 中之長莖全爪蟎陽莖圖可能誤植了。

全爪蟎屬中為害農作物者以柑桔葉蟎和歐洲葉蟎為中較為普遍，田間發生的歐洲葉蟎的捕食性昆蟲天敵一般為小黑瓢蟲類 (*Stethorus* spp.) 為主 (Parent 1973; Childers & Enns 1975; Laffi & Giovanni 1978; Injac & Dulič 1992; Liu *et al*. 1994; Hardman & Thistlewood 2002; Biddinger *et al*. 2009)；柑桔葉蟎則或以小黑瓢蟲類為主 (Jamieson *et al*. 2005; Abad-Moyano *et al*. 2009)，或以小黑隱翅蟲類 (*Oligota* spp.) 為主 (Kishimoto & Takagi 2001)。柑桔葉蟎在台灣的捕食性昆蟲天敵，包括小黑瓢蟲及小黑隱翅蟲，但以小黑瓢蟲為主 (Wen 1988; Wen *et al*. 1993)。筆者等在長莖全爪蟎族群中迄未發現小黑瓢蟲，與柑桔葉蟎和歐洲葉蟎的狀況有所不同，此點有待更多田間資料以確認。

誌謝

承 Tetsuo Gotoh 教授提供葉蟎種類鑑定之資訊，特此誌謝。

表 3. 長莖全爪蟎在其他植物上之採集紀錄及相關天敵。

Table 3. Collection records of *Panonychus elongatus* and associated predators on other plants.

Location	Date	m.a.s.l[z]	Coordinate	Host plant	Predators associated[y]
Highway 7a, Tatung, Ilan County					
10.5 K	2008/7/8	517 m	N24°33’00.8”, E121°27’27.9”	*Cerasus campanulata*	
20.2 K	2007/8/6	807 m	N24°28’30.9”, E121°25’4.8”	as above	Stigmaeidae
24.0 K	2008/7/8	949 m	N24°27’46.0”, E121°23’45”	as above	
24.5 K	2007/8/6	969 m	N24°27’45.5”, E121°23’46.9”	as above	
Xiulin, Hualien County					
Loshao	2007/7/30	1,146 m	N25°01’11.1”, E121°27’12.3”	*Humulus scandeus*	Phytoseiids, ceccidomyiid larvae
				Pueraria phasedoides	Many *Phytoseius* sp., with red marks on body.
Fushing, Taoyuan County					
Shanbaling	2008/7/7	1,176 m	N24°41’08.5”, E121°23’55”	*Sechium edule*	
	2008/9/10	1,147 m	N24°41’12.9”, E121°23’51.1”	*P. phasedoides*	
Nantou County					
Liyutan, Puli	2007/5/10	508 m	N23°58’23.3”, E120°59’35.8”	*Tabebuia chrysantha*	
Lushanwenchuan, Renai	2010/11/29	1,110 m	N24°01’24.5”, E121°11’21.3”	*Mallotus paniculatus*	
Chungkung[x]	1982/12			*Morus* sp.	
Taichung City					
Hoping	2008/10/20	523 m	N24°10’03.5”, E120°52’0.8”	*Pyrus pyrifolia*	*Amblyseius* spp.
Guguan	2007/5/29	849 m	N24°12’38.2”, E121°1’26.8”	*P. phasedoides*	
Tungshih Forest Garden	2007/5/22	468 m	N24°17’08.5”, E120°52’12.4”	*C. campanulata*	
Chungpu, Chiayi County					
Dongaka	2010/7/12	352 m	N23°20’45.7”, E120°31’1.1”	*Mallotus* sp.	
		552 m	N23°21’13.3”, E120°31’14.2”	*Morus* sp.	
Baihe, Tainan City					
Guanziling	2010/1/9	376 m	N23°19’50.4”, E120°30’13.2”	*Mallotus* sp.	*Phytoseius*, Cunaxidae
		397 m	N23°19’44.2”, E120°30’11.5”	*Manihot esculenta*	Ascidae

[z] m.a.s.l: Meters above sea level.
[y] Predator that was observed to feeding on *P. elongatus* is underlined.
[x] Data from Tseng (1990).

引用文獻

Abad-Moyano, R., T. Pina, O. Dembilio, F. Ferragut, and A. Urbaneja. 2009. Survey of natural enemies of spider mites (Acari: Tetranychidae) in citrus orchards in eastern Spain. Exp. Appl. Acarol. 47:49–61.

Biddinger, D. J., D. C. Weber, and L. A. Hull. 2009. Coccinellidae as predators of mites: Stethorini in biological control. Biol. Control 51:268–283.

Childers, C. C. and W. R. Enns. 1975. Predaceous arthropods associated with spider mites in Missouri apple orchards. J. Kans. Entomol. Soc. 48:453–471.

Hardman, J. M. and H. M. A. Thistlewood. 2002. *Panonychus ulmi* (Koch), European red mite (Acari: Tetranychidae). p.213–215. *in*: Biological Control Programmes in Canada, 1981–2000. (Mason, P. G. and J. T. Huber, eds.) CABI Publishing. New York. 608 pp.

Ho, C. C. 2004. *Oligonychus litchii* is an important agricultural pest in Taiwan (Acari: Tetranychidae). Plant Prot. Bull. 46:299–302. (in Chinese with English abstract)

Ho, C. C., K. C. Lo, and W. H. Chen. 1995. Spider mites injurious to economic plants in Taiwan and the toxicity of twelve acaricides to two major species. J. Agric. Res. China 44:157–165. (in Chinese with English abstract)

Ho, C. C., K. C. Lo, and W. H. Chen. 1997. Spider mite (Acari: Tetranychidae) on various crops in Taiwan. J. Agric. Res. China 46:333–346 (in Chinese with English abstract).

Ho, C. C., M. Y. Lin, S. H. Liang, and S. C. Wang. 2013. New members of the spider mite fauna in mango and pear orchards. Formosan Entomol. 33:57–66. (in Chinese with English abstract)

Ho, C. C., S. C. Wang, S. H. Liang, S. C. Chang, L. J. Cheng, H. Z. Lu, T. W. Chen, and W. J. Ko. 2011. Did European red mite and hawthorn spider mite dispersed out of Lishan area? Plant Prot. Bull. 53:19–28. (in Chinese with English abstract)

Injac, M. and K. Dulič. 1992. Population of phytophagous mites and occurrence of predators in apple orchards. Acta Phytopathol. Entomol. Hung. 27:299–304.

Jamieson, L. E., J. G. Charles, P. S. Stevens, C. E. McKenna, and R. Bawden. 2005. Natural enemies of citrus red mite (*Panonychus citri*) in citrus orchards. N. Z. Plant Prot. 58:299–305.

Kishimoto, H. and K. Takagi. 2001. Evaluation of predation on *Panonychus citri* (McGregor) (Acari: Tetranychidae) from feeding traces on eggs. Appl. Entomol. Zool. 36:91–95.

Laffi, F. and G. de Giovanni. 1978. Populations of phytophagous mites of apples and their predators. Ital. Agric. 115:111–119.

Liu, X., W. C. Shi, and J. R. Li. 1994. Study on quantitative dynamic and utilization prospect of natural enemies in apple orchard. Southwest China J. Agric. Sci. 7:76–81. (in Chinese with English abstract)

Lo, K. C., C. C. Ho, T. K. Wu, and S. R. Lin. 1986. Studies on population dynamics and integrated control of spider mites on pear in temperate zone of Taiwan. p.98–111. *in*: Special Publ. Ann. Conv. Agric. Assoc. China. 1986. Taipei, Taiwan. (in Chinese with English abstract)

Manson, D. C. M. 1963. Mites of the families Tetranychidae and Tenuipalpidae associated with citrus in south east Asia. Acarologia 5:351–364.

Manson, D. C. M. 1968. *Panonychus elongatus* Manson (Acarina: Tetranychidae)-A description and comparison with *P. citri* (McG.). J. Aust. Entomol. Soc. 7:6–10.

Parent, B. J. P. H. 1973. Natural population densities of the European red mite on apple in Quebec. Environ. Entomol. 2:1064–1068.

Tseng, Y. H. 1990. A Monograph of the Mite Family Tetranychidae (Acarina: Trombidiformes) from Taiwan. Taiwan Museum. Taipei, Taiwan. 224 pp.

Wen, H. C. 1988. Seasonal occurrence and chemical control of the citrus red mite [*Panonychus citri* (McGregor)] on carambola. J. Agric. Res. China 37:100–104. (in Chinese with English abstract)

Wen, H. C., H. H. Hao, and C. C. Lin. 1993. Seasonal occurrence and chemical control of the citrus red mite [*Panonychus citri* (McGregor)] on Indian jujube. J. Agric. Res. China 42:303–308. (in Chinese with English abstract)

Wu, K. C. and K. C. Lo. 1979. A new record spider mite, *Panonychus ulmi* (Koch) (Acarina: Tetranychidae) from Taiwan. J. Agric. Res. China 28:125–126. (in Chinese with English abstract)

Panonychus elongatus (Trombidiformes: Tetranychidae), a New Prosperous Crop Pest in Taiwan

Chyi-Chen Ho[1,*], Shun-Cheng Wang[2], Shih-Hsiang Liang[3], and Shu-Chen Chang[4]

Abstract

Ho, C. C., S. C. Wang, S. H. Liang, and S. C. Chang. 2018. *Panonychus elongatus* (Trombidiformes: Tetranychidae), a new prosperous crop pest in Taiwan. J. Taiwan Agric. Res. 67(2):218–223.

The survey in 2007–2010 indicated that high land peach was infested with *Panonychus elongatus* Manson in Taiwan. *Tetranychus kanzawai* Kishida was mainly found in low land peach orchards. Predators associated with the population of *P. elongatus* were also recorded.

Key words: Peach, Spider mite, Predator.

Received: April 7, 2017; Accepted: October 24, 2017.

* Corresponding author, e-mail: mtho2005@yahoo.com.tw

1 Former Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

2 Professor, Department of Environmental Engineering and Management, Chaoyang University of Technology, Taichung, Taiwan, ROC.

3 Assistant Research Fellow, Hsinchu Branch, Livestock Research Institute, Miaoli, Taiwan, ROC.

4 Assistant Research Fellow, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

台灣農業研究 (J. Taiwan Agric. Res.) 67(2):224–228 (2018)
DOI: 10.6156/JTAR.201806_67(2).0008

研究簡報

己酸緩和棉蚜 (*Aphis gossypii* Glover) 對小黃瓜侵襲

董耀仁[1] 許北辰[1,*]

摘要

董耀仁、許北辰。2018。己酸緩和棉蚜 (*Aphis gossypii* Glover) 對小黃瓜侵襲。台灣農業研究 67(2):224–228。

己酸處理植物已知能引發對不同病原微生物防禦反應，而植物遭受半翅目昆蟲危害時引起與受病原微生物危害時相似之防禦反應。本研究試驗小黃瓜以己酸處理對棉蚜 (*Aphis gossypii* Glover) 族群成長影響。試驗結果顯示，己酸浸泡或澆灌處理之小黃瓜，棉蚜族群成長顯著低於對照組，且效果隨著使用濃度增加提升。小黃瓜噴施 0.04% 及 0.08% 己酸，較對照組小黃瓜顯著影響棉蚜族群成長。己酸揮發處理小黃瓜，除 0.08% 處理組外，對棉蚜族群成長影響與對照組無差異。綜合上述試驗結果，己酸處理小黃瓜可緩和棉蚜侵襲，但效果受己酸處理方式及使用濃度影響。

關鍵詞：己酸、小黃瓜、棉蚜、誘導防禦。

前言

棉蚜 (*Aphis gossypii* Glover) 是世界性重要作物害蟲，在台灣棉蚜全年發生，寄主植物範圍廣，已記錄者包括 34 科 84 種植物，如葫蘆科、桑科及茄科等皆為其主要之寄主植物 (Shu 1980; Blackman & Eastop 1984; Tao 1990)。棉蚜因體型小、生活史短，繁殖能力強，一旦田間環境適宜，短時間族群能迅速增加造成嚴重危害 (Yu *et al*. 1997)。蚜蟲對植物之危害，除直接吸食韌皮部汁液影響植物生長外，其所分泌之蜜露於植物體表會進一步引發煤煙病影響光合作用。此外，蚜蟲是植物病毒之媒介昆蟲，其中棉蚜能傳播至少 76 種植物病毒，造成寄主植物的捲葉、生長不良，甚至死亡 (Chang *et al*. 1987; Chan *et al*. 1991; Kaygin *et al*. 2008)。

對於蚜蟲防治工作，農民以往多依賴噴施化學藥劑，惟因蚜蟲抗藥性發生、非標的生物與環境遭受毒害及消費者對農產品安全疑慮等問題，尋找安全有效之非農藥防治方法日漸受到重視 (Kerns & Gaylor 1992; Hsu *et al*. 2005; Gore *et al*. 2013)。

植物因無法移動以逃避環境中生物與非生物壓力。因此，植物發展出眾多的防禦策略以對抗環境中壓力 (Rasmann *et al*. 2012)。誘發 (priming) 為一種機制讓植物處於遭受生物或非生物壓力時能啟動更快速與有力防禦反應的生理狀態 (Conrath 2009)。

整合遺傳、基因組學及生物化學研究顯示，植物遭受半翅目昆蟲取食危害時所引起的防禦反應與遭受微生物病原入侵時類似 (Kaloshian & Walling 2005; Howe & Jander 2008)。前人研究顯示，施用可誘發植物對病原防禦反應的維生素 B1 (thiamine)，可降低稻麥蚜 (*Rhopalosiphum padi* Linnaeus)、麥長管蚜 (*Sitobion avenae* Fabricius) 及豌豆蚜 (*Acyrthosiphon pisum* Harris) 對大麥及豌豆之危害 (Hamada & Jonsson 2013)。

己酸 (hexanoic acid) 是一種單羧酸，已知存在於草莓 (*Fragaria vesca* Linnaeus) 及楊梅 (*Arbutus unedo* Linnaeus) (Soufleros *et al*. 2005; Aranega-Bou *et al*. 2014) 中，為一種天然化合物。前

投稿日期：2017 年 8 月 3 日；接受日期：2017 年 10 月 31 日。
* 通訊作者：bchen@tari.gov.tw
[1] 農委會農業試驗所應用動物組助理研究員。台灣 台中市。

人研究顯示，己酸可誘發不同植物對不同病原微生物之防禦反應，是一種廣效性天然誘導物 (Aranega-Bou *et al*. 2014)。至目前為止，尚無己酸對小黃瓜綿蚜影響之研究結果。因此，本試驗將探討可誘發植物防禦反應之己酸施用於小黃瓜是否對棉蚜族群成長造成影響，藉由此研究我們希望未來能發展一安全、有效的棉蚜防治方法。

材料與方法

試驗用材料己酸 (≥ 98%) 及乙醇 (≥ 99.9%) 購自於台灣默克股份有限公司，供試小黃瓜新蜜購自德城行有限公司，泥炭土 (Potgrond H, Klasmann-Deilmann Gmbh, Germany)、塑膠盆 (直徑 9 cm，高 7 cm)、透明玻璃樣本瓶 (直徑 2 cm，高 6 cm) 及透明壓克力箱 (40 cm × 40 cm × 40 cm) 均購自振詠興業公司，棉蚜種源來自行政院農業委員會農業試驗所余志儒博士研究室，飼育方法參考 Yu *et al*. (1997)，但改用小黃瓜來繁殖棉蚜。

本試驗方法參考 Hamada & Jonsson (2013)，其中種子浸泡試驗為將己酸以 0.1% 乙醇配成 0.08、0.04、0.02、0.01 及 0% 後，分別取 10 mL 加入透明玻璃樣本瓶中後，放入小黃瓜種子。經 10 h 後，將小黃瓜種子植入含泥炭土之塑膠盆中，並移至定溫養蟲室，室內溫度 25℃ ± 1℃，光週期 16 L：8 D。待小黃瓜已長出 2 片真葉後，於第一片真葉上參照 Yu *et al*. (1997) 所使用方法，接入 10 隻 1 日齡棉蚜，經 10 d 後，觀察記錄小黃瓜植株上棉蚜數量，本試驗 10 重複。噴施試驗為將小黃瓜植株分別噴施 10 mL 不同濃度己酸，經 1 d 後同浸泡試驗方式接入 10 隻 1 日齡棉蚜，再經 10 d 後，觀察記錄小黃瓜植株上棉蚜數量，本試驗 10 重複。澆灌試驗為將小黃瓜植株分別澆灌 20 mL 不同濃度己酸，經 1 d 後同浸泡試驗方式接入 10 隻 1 日齡棉蚜，再經 10 d 後，觀察記錄小黃瓜植株上棉蚜數量，本試驗 10 重複。揮發性試驗則為將小黃瓜植株放入透明壓克力箱中，壓克力箱內上方已放置 1 張直徑 9 cm 濾紙 (已分別添加 100 μL 不同濃度己酸)。經 2 h 後將小黃瓜植株移出，同浸泡試驗方式接入 10 隻 1 日齡棉蚜，再經 10 d 後，觀察記錄小黃瓜植株上棉蚜數量，本試驗 10 重複。

試驗所得各項資料先以 SAS-EG (Version 7.1, 2014) 統計分析軟體，進行變方分析 (analysis of variance; ANOVA) 後，再以最小顯著差異性測驗 (least significant difference test; LSD test) 分析其差異顯著性。

結果與討論

小黃瓜種子浸泡不同濃度己酸較對照組顯著影響棉蚜族群成長，且效果隨著己酸濃度增加而提高 (圖 1)。以不同濃度己酸噴施小黃瓜，結果 0.04% 及 0.08% 己酸處理組棉蚜數目顯著低於對照組，0.01% 及 0.02% 己酸處理組棉蚜數量與對照組間無差異 (圖 2)。小黃瓜澆灌不同濃度己酸較對照組顯著影響棉蚜族群成長，且效果隨著己酸濃度增加而提高，惟 0.04% 及 0.08% 己酸處理組間棉蚜數量無顯著差異 (圖 3)。不同濃度己酸揮發處理小黃瓜，除 0.08% 己酸處理組外，其餘濃度己酸處理組與對照組間棉蚜數量無顯著差異 (圖 4)。

誘導抗病物質於以往研究中，已證實可誘發植物對不同病原微生物抗性 (Aranega-Bou *et al*. 2014; Llorens *et al*. 2017)，而半翅目刺吸式口器昆蟲取食誘導植物所產生之防禦反應與植物受病原微生物危害時類似 (Kaloshian & Walling 2005)。本試驗證實，己酸施用於小黃瓜可影響棉蚜族群發展，而前人研究亦證實維生素 B1 可影響蚜蟲於大麥及豌豆上族群發展 (Hamada & Jonsson 2013)，顯示誘導抗病物質具有減緩蚜蟲等刺吸式口器害蟲對植物危害之潛力。

本試驗中不同濃度己酸以種子浸泡及澆灌方式，均對棉蚜族群發展造成影響，但噴施處理中僅 0.04% 及 0.08% 己酸處理組棉蚜族群發展受影響。此外，己酸揮發處理試驗中，只有 0.08% 己酸處理影響棉蚜族群發展，顯示利用己酸處理小黃瓜以減緩棉蚜侵襲會受施用方式及使用濃度影響。未來仍需進一步確認己酸處理小黃瓜之最佳應用方式及施用濃度，並於田間測試減緩棉蚜危害之效果，以評估己酸用於棉蚜防治之可行性。

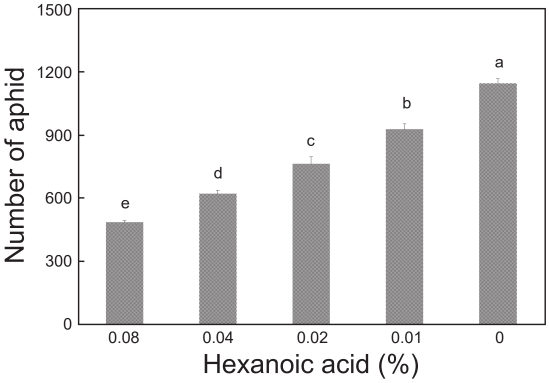


圖 1. 己酸浸泡處理小黃瓜對棉蚜 (*Aphis gossypii* Glover) 族群成長影響。各平均值示以相同字母者為 5% 顯著水準下經最小顯著差異性測驗 (least significant difference test; LSD test) 未達顯著性差異。

Fig. 1. Effect of hexanoic acid soaking treatments of the population growth of aphids (*Aphis gossypii* Glover) on cucumber plants. Means followed by the same letter(s) are not significantly different at $P < 0.05$ (least significant difference test; LSD test).

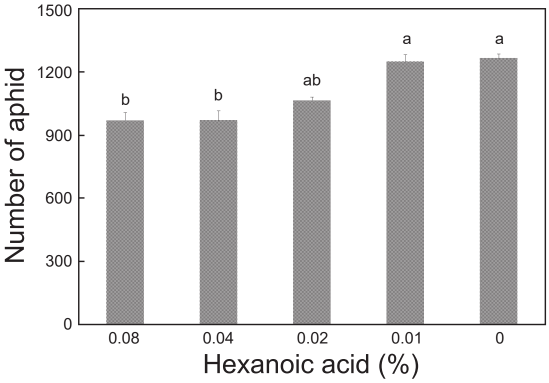


圖 2. 己酸噴施處理小黃瓜對棉蚜 (*Aphis gossypii* Glover) 族群成長影響。各平均值示以相同字母者為 5% 顯著水準下經最小顯著差異性測驗 (least significant difference test; LSD test) 未達顯著性差異。

Fig. 2. Effect of hexanoic acid spraying treatments of the population growth of aphids (*Aphis gossypii* Glover) on cucumber plants. Means followed by the same letter(s) are not significantly different at $P < 0.05$ (least significant difference test; LSD test).

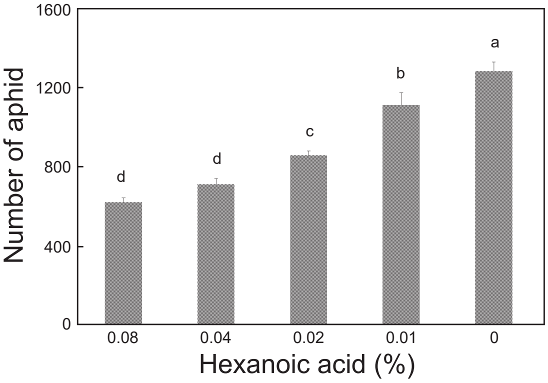


圖 3. 己酸澆灌處理小黃瓜對棉蚜 (*Aphis gossypii* Glover) 族群成長影響。各平均值示以相同字母者為 5% 顯著水準下經最小顯著差異性測驗 (least significant difference test; LSD test) 未達顯著性差異。

Fig. 3. Effect of hexanoic acid irrigating treatments of the population growth of aphids (*Aphis gossypii* Glover) on cucumber plants. Means followed by the same letter(s) are not significantly different at $P < 0.05$ (least significant difference test; LSD test).

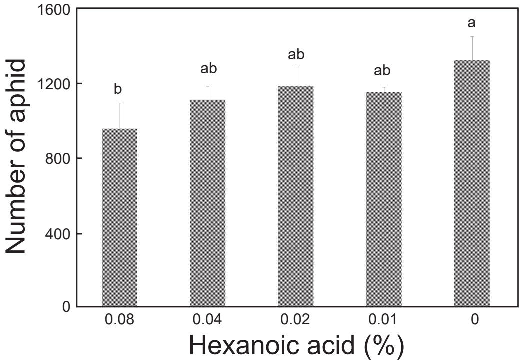


圖 4. 己酸揮發處理小黃瓜對棉蚜 (*Aphis gossypii* Glover) 族群成長影響。各平均值示以相同字母者為 5% 顯著水準下經最小顯著差異性測驗 (least significant difference test; LSD test) 未達顯著性差異。

Fig. 4. Effect of hexanoic acid volatile treatments of the population growth of aphids (*Aphis gossypii* Glover) on cucumber plants. Means followed by the same letter(s) are not significantly different at $P < 0.05$ (least significant difference test; LSD test).

引用文獻

Aranega-Bou, P., M. de la O. Leyva, I. Finiti, P. García-Agustín, and C. González-Bosch. 2014. Priming of plant resistance by natural compounds: Hexanoic acid as a model. Front. Plant Sci. 5:488.

Blackman, R. L. and V. F. Eastop. 1984. Aphids on the World's Crops: An Identification and Information Guide. Wiley Press. New York. 466 pp.

Chan, C. K., A. R. Forbes, and D. A. Raworth. 1991. Aphid-transmitted Viruses and Their Vectors of the World. Research Branch, Agriculture Canada. Ontario, Canada. 216 pp.

Chang, Y. M., C. H. Hsiao, W. Z. Yang, S. H. Hseu, Y. J. Chao, and C. H. Huang. 1987. The occurrence and distribution of five cucurbit viruses on melon and watermelon in Taiwan. J. Agric. Res. China 36:389–397. (in Chinese with English abstract)

Conrath, U. 2009. Chapter 9 Priming of induced plant defense response. Adv. Bot. Res. 51:361–395.

Gore, J., D. Cook, A. Catchot, B. R. Leonard, S. D. Stewart, G. Lorenz, and D. Kerns. 2013. Cotton aphid (Heteroptera: Aphididae) susceptibility to commercial and experiment insecticides in the southern United States. J. Econ. Entomol. 106:1030–1439.

Hamada, A. M. and L. M. V. Jonsson. 2013. Thiamine treatments alleviate aphid infestations in barley and pea. Phytochemistry 94:135–141.

Howe, G. A. and G. Jander. 2008. Plant immunity to insect herbivores. Annu. Rev. Plant Biol. 59:41–66.

Hsu, J. C., G. L. Li, and H. T. Feng. 2005. Susceptibility of cowpea aphid (*Aphis craccivora*), cotton aphid (*Aphis gossypii*), turnip aphid (*Lipaphis erysimi*), and green peach aphid (*Myzus persicae*) to several insecticides in Taiwan. Plant Prot. Bull. 47:115–127. (in Chinese with English abstract)

Kaloshian, I. and L. L. Walling. 2005. Hemipterans as plant pathogens. Annu. Rev. Phytopathol. 43:491–521.

Kaygin, A. T., G. Gorur, and F. Cota. 2008. Contribution to the aphid (Homoptera: Aphididae) species damaging on woody plants in Bartin, Türkiye. Int. J. Nat. Eng. Sci. 2:83–86.

Kerns, D. L. and M. J. Gaylor. 1992. Insecticide resistance in field population of the cotton aphid (Homoptera: Aphididae). J. Econ. Entomol. 85:1–8.

Llorens, E., G. A. Pilar, and L. Lapena. 2017. Advances in induced resistance by natural compounds: Towards new options for woody crop protection. Sci. Agric. 74:90–100.

Rasmann, S., M. De Vos, and G. Jander. 2012. Ecological role of transgenerational resistance against biotic treats. Plant Signal. Behav. 7:447–449.

Shu, T. C. 1980. Contributions to the Study of Aphididae of Taiwan. Ph.D. Dissertation, Department of Plant Pathology and Entomology, National Taiwan University. Taipei, Taiwan. 283 pp. (in Chinese)

Soufleros, E. H., S. A. Mygdalia, and P. Natskoulis. 2005. Production process and characterization of the traditional Greek fruit distillate 'Koumaro' by aromatic and mineral composition. J. Food Compos. Anal. 18:699–716.

Tao, C. C. 1990. Aphid-fauna of Taiwan Province, China. Taiwan Museum Press. Taipei, Taiwan. 327 pp. (in Chinese)

Yu, J. Z., Y. C. Liu, and B. H. Chen. 1997. Resistance of three muskmelon cultivars to *Aphis gossypii* Glover (Homoptera: Aphididae). Chinese J. Entomol. 17:245–256. (in Chinese with English abstract)

Hexanoic Acid Alleviated Cotton Aphid (*Aphis gossypii* Glover) Infestations in Cucumber

Yaw-Jen Dong[1] and Bei-Chen Hsiu[1,*]

Abstract

Dong, Y. J. and B. C. Hsiu. 2018. Hexanoic acid alleviated cotton aphid (*Aphis gossypii* Glover) infestations in cucumber. J. Taiwan Agric. Res. 67(2):224–228.

Treatment of plants with hexanoic acid has been shown to induce plant defense against microorganisms. Responses of plant to hemipteran herbivores have substantial overlap with responses mounted against microbial pathogens. In this research, we studied the effects of hexanoic acid treatments of cucumber plant on cotton aphid (*Aphis gossypii* Glover) population growth. Results showed that significantly lower cotton aphid numbers were found on cucumber plants grown from seeds soaked in hexanoic acid solution treatments or irrigated with hexanoic acid treatment than control and the effect increases with increasing concentration of hexanoic acid. Spraying cucumber plants with 0.04% and 0.08% hexanoic acid resulted in significantly reduced cotton aphid population growth than control. Besides 0.08% hexanoic acid volatile treatment, there was no difference of cotton aphid population growth between other hexanoic acid treatments and control. In summary, results of our research showed that hexanoic acid could reduce cotton aphid population growth on cucumber plants but the effect varied with concentrations and treatment methods.

Key words: Hexanoic acid, Cucumber, Cotton aphid, Induced resistance.

Received: August 3, 2017; Accepted: October 31, 2017.
* Corresponding author, e-mail: bchen@tari.gov.tw
1 Assistant Research Fellows, Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

Editorial Board

Editor-in-Chief

Yang, Chwen-Ming
Division of Crop Science, Taiwan Agricultural Research Institute

Editors

Ann, Pao-Jen
Division of Plant Pathology, Taiwan Agricultural Research Institute
Chang, Ruey-Jang
Division of Plant Pathology, Taiwan Agricultural Research Institute
Chang, Yung-Ho
Department of Food and Nutrition, Providence University
Chen, Chien-Chung
Division of Applied Zoology, Taiwan Agricultural Research Institute
Chen, Chiling
Division of Agricultural Chemistry, Taiwan Agricultural Research Institute
Chen, Chung-Li
Department of Agronomy, National Chung Hsing University
Chen, Iou-Zen
Department of Horticulture and Landscape Architecture, National Taiwan University
Chen, Su-Ming
Department of Bio-Industrial Mechatronics Engineering, National Taiwan University
Chen, Yu-Hui
Department of Agricultural Economics, National Taiwan University
Chien, Li-Hsien
Department of Applied Economics, National Chung Hsing University
Chung, Wen-Hsin
Department of Plant Pathology, National Chung Hsing University
Do, Yi-Yin
Department of Horticulture and Landscape Architecture, National Taiwan University
Hou, Feng-Nan
Department of Entomology, National Chung Hsing University
Huang, Chao-Chia
Division of Crop Science, Taiwan Agricultural Research Institute
Huang, Jenn-Wen
Department of Plant Pathology, National Chung Hsing University
Huang, Pung-Ling
Department of Horticulture and Landscape Architecture, National Taiwan University
Huang, Yuh-Ming
Department of Soil and Environmental Sciences, National Chung Hsing University
Juang, Kai-Wei
Department of Agronomy, National Chiayi University
Kao, Ching-Huei
Department of Agronomy, National Taiwan University
Ko, Chiun-Cheng
Department & Graduate Institute of Entomology, National Taiwan University
Ku, Hsin-Mei
Department of Agronomy, National Chung Hsing University
Kuo, Bau-Jeng
Department of Agronomy, National Chung Hsing University
Lin, Huey-Ling
Department of Horticulture, National Chung Hsing University
Lin, Yann-Rong
Department of Agronomy, National Taiwan University
Liu, Li-Yu
Department of Agronomy, National Taiwan University
Lu, Hsiu-Ying
Miaoli District Agricultural Research and Extension Station
Lu, Kuang-Hui
Department of Entomology, National Chung Hsing University
Shen, Wei-Chiang
Department of Plant Pathology and Microbiology, National Taiwan University
Tsay, Jyh-Rong
Taiwan Agricultural Research Institute
Tseng, Menq-Jiau
Department of Horticulture, National Chung Hsing University
Tzou, Yu-Min
Department of Soil and Environmental Sciences, National Chung Hsing University
Wang, Chan-Sen
Department of Agronomy, National Chung Hsing University
Wang, Shu-Jen
Department of Agronomy, National Taiwan University
Wu, Wen-Jer
Department & Graduate Institute of Entomology, National Taiwan University
Yang, Jeng-Tze
Department of Entomology, National Chung Hsing University
Yen, Gow-Chin
Department of Food Science and Biotechnology, National Chung Hsing University

Editorial Assistants

Wang, Li-Jung
Editorial Office of Journal of Taiwan Agricultural Research
Wang, Zi-Yu
Editorial Office of Journal of Taiwan Agricultural Research
Wu, Huei-Ching
Division of Technical Service, Taiwan Agricultural Research Institute

Consultant to Editorial Assistants

Wu, Yi-Yan
Division of Technical Service, Taiwan Agricultural Research Institute

JOURNAL OF TAIWAN AGRICULTURAL RESEARCH

Vol. 67 No. 2 June 30, 2018

Published by Taiwan Agricultural Research Institute, Council of Agriculture

Publisher	Junne-Jih Chen
Editor-in-Chief	Chwen-Ming Yang
Address	No.189, Zhongzheng Rd., Wufeng Dist., Taichung City 41362, Taiwan, ROC
Website	http://www.tari.gov.tw; E-mail: jtar@tari.gov.tw; Tel: +886-4-2331-7236
Submission	http://aspers.airiti.com/JTAR
Press	Airiti Press
Address	18F., No.80, Sec.1, Chenggong Rd., Yonghe Dist., New Taipei City 23452, Taiwan, ROC
Tel	+886-2-2926-6006
E-mail	press@airiti.com
Price	NT$ 175 (per copy)
Distributor	1. GB Books / 1F., No.209, Songjiang Rd., Taipei City 10485, Taiwan, ROC GB Website: http://www.govbooks.com.tw; Tel: +886-2-2518-0207 2. Wunan Books / No.6, Zhongshan Rd., Taichung City 40042, Taiwan, ROC Tel: +886-4-2226-0330